Teachers as Designers: The Iterative Process of Curriculum Design Focused on STEM Integration

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Dedication

To Mandi, always.

Abstract

Curricular resources play an important role when educational reform efforts are introduced (Powell & Anderson, 2002). *Taking Science to School* (NRC, 2007) and more recently the *Next Generation Science Standards* [NGSS] (NGSS Lead States, 2013) have advocated for changes related to standards, curriculum, and teacher learning. Previous science standards (NRC, 1996) have been set aside as two transformational documents have taken the forefront in U.S. science education. *The Framework for K-12 Science Education* (NRC, 2012) and the succeeding NGSS are aimed at providing a new structural organization for science education that now includes *engineering practices*. The integration of science and engineering practices presents new opportunities and challenges for teachers as they must now design learning experiences that integrate science, mathematics, and engineering concepts. Teachers are not typically asked to be curriculum designers (Penuel, Roschelle, & Shechtman, 2007; Reiser et al., 2000) and when they are asked to be designers face unique challenges. There are limited studies (e.g. Boschman, McKenney, & Voogt, 2014) that directly investigate teachers during the curriculum design process and multiple calls to further explore teachers during the curriculum design process (Huizinga, 2014; Penuel & Gallagher, 2012; Voogt, et al., 2011).

This study explores the actions and conversations of nine elementary science teachers during the curriculum design process while they design and develop a science, technology, engineering, and mathematics [STEM] integrated curricular unit. Teachers in the study worked in small teams and were paired with a coach during the design process.

The study was framed around the participatory relationship that exists between teachers and curriculum (Remillard, 2005; Brown, 2002) and the view that curriculum design is a design problem that requires uniquely human interpersonal responses (Jonassen, 2000; 2011). This applied case study (Merriam, 2009) employed an inductive analysis and creative synthesis that followed the analysis strategies of constructed grounded theory (Charmaz, 2006; Glaser & Straus, 1967). Data collected from a 12-day professional development opportunity included audio-recorded curriculum design conversations of three unique teams (~3000 minutes), 12 individual interviews, daily participant reflections, and curriculum design artifacts.

The study's major theoretical assertion is that teachers need encouragement to be innovative during the curriculum design process due in part to their tendency to design and develop curriculum resources similar to those they have used in the past. Teachers strongly considered their own classroom contexts during the design process and therefore primarily designed resources they could use in their own classroom. Secondly, curriculum design needs to be considered a design problem with no concrete solution that therefore warrants all participants be made aware of and prepared to discuss the complexities and propositions required of each designer (Remillard, 2005) during the curriculum design process.

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Chapter I: Introduction

National Calls for STEM and Engineering Education

Increased attention to science, technology, engineering, and mathematics [STEM] education has been advocated for in national policy because of economic and political influences (National Research Council [NRC], 2011; 2012; 2014). The United States [U.S.] Labor Department (2010) maintains that attracting a new generation of students to STEM-related fields is essential to maintaining the country's global economic competitiveness and status as the world's leader in innovation. However, currently there is a decreasing trend of graduation rates in advanced STEM degrees, which creates an additional driver for this increased national attention on STEM education. Other national documents (Donofrio & Whitefoot, 2015; Litan, Wyckoff, & Fealing, 2014) have also made a connection between a workforce with STEM degrees and a country's economic prevalence and national security (NRC, 2007). For example, the report *Rising Above the Gathering Storm* signaled the importance of science and engineering by stating, "a primary driver of the future economy and concomitant creation of jobs were *innovation*, largely derived from advances in science and engineering" (NRC, 2006; p. 2). While some have cautioned that the STEM pipeline crisis may be more of a myth, fueled by political, industrial, and economic forces, the reality remains that funding for STEM education and its subsequent prevalence in national science standards (NRC, 2012; Next Generation Science Standards [NGSS] Lead States, 2013) will persist in K-12 science classrooms.

Unfortunately, calls for reform of science education in the U.S. (American Association for the Advancement of Science [AAAS], (AAAS, 1989,1993) (NRC, 1996, 2000) have largely gone unanswered as it continues to revolve around the teaching of, “discrete facts with a focus on breadth over depth, and does not provide students with engaging opportunities to experience how science is actually done” (NRC, 2012; p. 1). As astronomer Carl Sagan (1995) once infamously said, "We live in a world exquisitely dependent on science and technology, in which hardly anyone knows anything about science and technology”. Indeed, today’s technology-driven, knowledge-based economy (Pink, 2005) requires an educational environment willing to enact change and engage *all* learners to explore the natural world via the STEM disciplines.

Taking Science to School (NRC, 2007) and more recently the NGSS (NGSS Lead States, 2013) have advocated for changes in standards, curriculum, instruction, assessment, and teacher learning. Previous standards put forth by the National Academy of Science (e.g. National Science Education Standards [NSES] (NRC, 1996), have been placed aside as two transformational documents have taken the forefront in U.S. science education. The Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas [hereby referred to as The Framework] (NRC, 2012) and the resulting NGSS (NGSS Lead States, 2013) are aimed at providing a structural organization for the three dimensions of science education that now includes *science and engineering practices.* The integration of science and engineering practices presents new opportunities and challenges for teachers, as they must now design learning experiences that also include the work of engineers. The combination of new content standards that can be integrated and the call for curriculum reform provides a spark for change. This call for change can then build off of the identified connection between research-based curriculum and student achievement (Roschelle et al., 2010) and the identified role curriculum materials have in ushering educational reform efforts (Powell & Anderson, 2002). These changes present opportunities and challenges that can be addressed with curriculum development efforts that take into account new content standards and involve teachers and those vested at working with teachers via professional development projects.

Unfortunately, the type of supports needed for teachers involved in professional development focused on developing curricular innovations is limited (Penuel, & Gallagher, 2009; Penuel & Fishman, 2012). Traditionally, researchers have focused on the implementation of a researcher-designed curriculum by examining the impact of these curriculum materials on student learning, often by using standardized assessments. Teachers are not typically asked to be designers (Penuel, Roschelle, & Shechtman, 2007; Reiser et al., 2000) and when asked to design curriculum, face unique challenges (e.g. connecting core disciplinary ideas and adapting to diverse student needs). The research base on how to develop teachers' knowledge and skills related to curriculum design is in its primacy (Brown, 2002; Brown, 2009).

There are a few recent studies that investigate teachers during the curriculum design process (Boschman, McKenney, & Voogt, 2014; Penuel & Gallagher, 2012; Voogt, et al., 2011). This movement has been impelled by the demonstrated benefits in professional growth of teachers involved in curriculum design (George & Lubben, 2002) and the intimate relationship that exists between teachers and the curriculum (Remillard, 2005). The notion of treating teachers as designers has been expanded on by the works of Brown (2002; 2009). Voogt, et al. (2011) conducted the first ever systematic review of the literature on teacher design teams and identified 9 studies that investigated teacher learning during the design of curricular materials. The study concluded that “learning processes are encouraged and knowledge is constructed” (Voogt, et al., 2011; p. 1244) when teachers are involved designing curriculum for classroom use. A study by Pickering (2013) investigating the interactions of teachers and graduate students tasked with building integrated STEM curricular units has further defined design teams by including non-school orientated individuals.

The development of curriculum and the design process that is intimately connected to this process are of interest to the community of researchers vested in working with teachers during curriculum design. However, the process of initiating and promoting teacher planning and curriculum design is in development. Huizinga et al. (2014) focused on developing teachers’ design expertise in a small scale, exploratory study that identified three gaps in teachers’ design expertise: curriculum design expertise, pedagogical content knowledge, and curricular consistency expertise. Huizinga et al. (2014) call for further research to, “examine more closely how support is designed and offered in real-time during collaborative design processes, if and how the current guidelines are applied, and how support affects teachers’ design expertise” (p. 55). Voogt, et al. (2011) furthered the call for further investigation of teacher design teams, advocating for, “more research on the composition of the teams, the nature of the design task, the role of the external facilitator and the interactions in Teacher Design Teams is needed to better understand how design teams can contribute to professional learning" (p. 1243).

Curriculum design can justly be considered a design problem, due to its ill-structured and complex nature (Jonassen, 2000). Teachers have a deep knowledge of local contexts that are invaluable to curriculum development that when harnessed have the capability to develop meaningful learning experiences. Given that teachers are key informants of what transpires in classrooms, their lesson planning, assignments and curricular units can provide key insights into how proposed reforms efforts such as integrated STEM, could be enacted. However, the curriculum design process that generates these teaching activities is largely ignored. Instead researchers focus on teachers' implementation of researcher-designed curriculums, by observing them in action months after experiencing a specific professional development experience (Penuel, McWilliams, McAuliffe, Benbow, Mably, & Hayden, 2008). The roles teachers take on during curriculum design and the type of professional development support needed to foster teachers during the design process is largely unexplored in the teacher professional development literature (Voogt et al., 2011). Therefore, a study aimed at further exploring the behaviors, actions, and roles teachers exhibit during a professional development experience centered around STEM-integrated curriculum design is warranted. It is also of interest to examine a specific support such as coaching during the curriculum design process to better understand how this impacts and influences teachers during the design process.

Purpose of the Study

This study is primarily intended to explore the curriculum design process of science teachers tasked with integrating STEM into their elementary school classroom. The study aims to provide insights into the following phenomenon: (1) The curriculum design actions of teachers focused on STEM integration (2) The negotiation of roles as exhibited by teams of teachers and coaches during the curriculum design process. (3) The pronounced and hidden drivers that influence teachers' design decisions while they design curriculum focused on STEM integration.

Research Questions

The overarching research question for this applied and qualitative research study is: *How do collaborative teams of teachers and coaches engage in the curriculum design process while co-developing a curricular unit focused on STEM integration for their classrooms?* The supplemental research questions that support the overarching research question are:

1. What are the intuitive and orchestrated curriculum design practices of science teachers and coaches while they co-design a curricular unit focused on STEM integration?
2. How do science teachers and coaches negotiate their roles as curriculum designers in a collaborative team while creating a curricular unit focused on STEM integration?

3. How do coaches view and enact their roles as mediators and collaborators while co-developing a curricular unit focused on STEM integration with science teachers?

4. What influences predominately impact and influence a curriculum design team's decisions during the creation of a curricular unit focused on STEM integration?

Chapter II: Review of the Literature

The History Curriculum Reform in Science Education

Curriculum design and development came to the forefront of science and mathematics education in the 1960's due to congressional action that allocated roughly 10% of the education budget for curriculum reform (Rudolph, 2002). This funding was intended to increase interest in science and technology fields in response to the Soviet launch of *Sputnik* as the U.S. aimed to enhance national security by becoming the world's most advanced, technologically superior nation. These initial efforts at curriculum reform were launched with the notion that the country's scientists and engineers should design curriculum for teachers to implement in the classroom. Bruner (1960) highlighted this proposition by pointing out that only, "the best minds in any particular discipline must be put to work on the task" (p. 19). Unfortunately, teachers are not mere conduits for educational reforms in that they adapt curriculum materials accordingly as they implement (Bridgham, 1971; Berman & McLaughlin, 1975). McGlaughlin (1976) pointed out that early attempts at giving teachers pre-fabricated curriculum fell short of expectations because of the ignorance of curriculum developers to the realities of a teacher's classroom context. As researchers began to further understand that a teacher's decisions (Welch, 1979) influenced how a curriculum was implemented, the movement toward taking into account the "mutual adaptation" (Berman & McLaughlin, 1978) of curriculum reforms began.

The next significant curriculum reform efforts were triggered by the Commission on Educational Excellence's report in 1983, *A Nation at Risk*. This report ushered in the standards and accountability era of educational reform and also resulted in the creation of two foundational documents in science education: *Science for All Americans* (Rutherford & Ahlgren, 1989) and the *Benchmarks for Science Literacy* (AAAS, 1993) which were followed by the NSES (NRC, 1996). Teacher adaption of curriculum innovations was still ignored as the public and researchers still sought "teacher-proof" curriculum material, while noting the importance of exposing students to a scientifically and pedagogically sound curriculum (Atkin & Black, 2003).

Researchers working on curriculum design projects began to better understand how teachers adapt curriculum materials (Clandinin & Connelly, 1991) and the interpretation process (Ben-Peretz, 1990) that transpires during adaptation. Consequently, researchers took a more interpretive view of teachers, curriculum, and the curriculum design process as teachers attempted to adapt curriculum for their own classroom. Similarly, researchers also unveiled how these interpretations could result in "lethal mutations" (Brown & Campione, 1996) as a developer's initial intentions were transformed beyond original intent (Reiser et al., 2000; Atkin & Black, 2003). It soon became a priority to not only understand more about what a teacher brings to curriculum design and subsequent implementation, but also to take into account how a curricular innovation unfolds in a classroom context over time with the aims of better understanding how to ensure long-term success.

Teachers commonly do not think of themselves as designers when asked to be a part of the design process (Reiser et al., 2000; Penuel et al., 2007) despite the potential advantages of designing, implementing, and redesigning a curriculum unit for their classroom (Spillane 1999; 2004). It is important to consider the important role teachers can potential play during curriculum design because in the end, student learning is intricately connected to the actions of teachers (Spillane, 1999). Today, “there is a growing recognition of the necessity and desirability of preparing teachers to make effective decisions in designing instructional experiences for students with curricula” (Penuel et al., 2009; p. 464) due to this reality. Unfortunately, many teachers experienced difficulties when confronted with the challenge of adopting their practice to incoming reforms (Reiser et al., 2000; Sherin, 2002), so involving them on the ground floor of curriculum design should also be done with caution.

Current Views of Teachers and Curriculum Development

Contemporary professional development more often involves teachers in full-scale curriculum development projects (Penuel & Gallagher, 2009; Penuel et al., 2008). A major purpose for involving teachers in the design process includes ongoing teacher development (Ball & Cohen, 1996; Borko, 2004; Parke & Coble, 1997; Schwartz & Gwekwerer, 2007). It has also been reported that teacher practice can be triggered by curriculum design (Drake & Sherin, 2006). Another reason for involving teachers in the process of design is the reality that teachers are on the ground floor of any proposed curricular change (Keys & Bryan, 2001; Parke & Coble, 1997). By taking into account a teacher’s social context through their involvement in the curriculum design process, uptake or resistance of a curricular innovation can be impacted (Rivet, 2006) as involving teachers in the design process creates a sense of ownership (Bakah, Voogt, & Pieters, 2012; Carlgren, 1999; Handelzalts, 2009) from design to implementation. As researchers and curriculum developers attend to using curriculum materials in educative ways, teachers are more seminal to the curriculum development process (Davis & Krajcik, 2005) creating an imperative to develop teachers' curriculum design capacities (Brown, 2009; Bybee, 1997; Schwarz & Gwekwerere, 2007).

Theoretical Perspectives

Moving the focus away from how teachers augment, adapt, subvert, and outright change curriculum materials, Remillard (2005) and later Brown (2009) have theorized the relationship between teachers and curriculum materials. Remillard (2005) accomplishes this by describing the teacher-curriculum relationship as being participatory and collaborative in nature. Curriculum materials have a "mode of address" (Remillard, 2012) that speak to teachers in certain ways while making assumptions about the intended audience. The use of a particular curriculum activates a transformational process that can enable or constrain a teacher's decision-making ability. Curriculum materials are shaped by historical, cultural, and social values, dare multifaceted and contain suggestions about what science topics to teach and how to teach them. Remillard's (2005) framework conceptualizes, and later describes four principle constructs: (a) the teacher, (b) the curriculum, (c) the participatory relationship between them, and (d) the resulting planned and enacted curricula. Remillard (2005) further suggests that, "teachers are engaged in design work throughout the multiple domains of teaching" (p. 236) and that, "for many teachers, the process of interacting or participating with a new curriculum is neither explicit nor public" (p. 239). This framework and the participatory relationship it exemplifies carve out space for the current study involving teachers designing curriculum for themselves and outside audiences. Lastly, as Remillard (2005) proclaims, "the designers of curriculum materials, as well as those who adopt them, must carefully consider how they frame and support the teacher–curriculum relationship" (p. 241).

Brown (2009) presented a conception of curriculum, and the actions it affords or constrains, as a “cultural artifact or tool”. He does this by drawing on sociocultural theory (Wartofsky, 1973) and further suggests that curriculum materials are a “mediational means” (Wertsch, 1991; 1998) that, "represent and transmit such modes of action through social and cultural arrangements” (p. 19). Curriculum materials (lesson plans, teacher guides, and textbooks), according to Brown (2009) are, "culturally rooted tools that represent and transmit modes of action” (p. 21). In taking up the theoretical underpinning put forth by Brown (2009), three key points can be taken up that further our understanding of the interaction between teachers and curriculum:

> (a) curriculum materials play an important role in affording and constraining teachers’ actions;
>
> (b) teachers notice and use such artifacts differently given their experience, intentions, and abilities; and
>
> (c) “teaching by design” is not so much a conscious choice as an inevitable reality. (p. 40)

Brown (2002) closely followed three middle school science teachers using an inquiry-based curricular unit. In the study, teachers utilized curriculum resources in varying ways and participated with curriculum resources in three ways, at varying points during the unit: offloading responsibility, adapting curriculum resources, and deviating away from curriculum resources by improvising. Theoretically framing the relationship between teachers and the curriculum they create and enact, while also positing that teaching is a form of design, from conception to implementation, a more focal lens is created for viewing the actions and behaviors of teachers during the design process.

Curriculum Development as a Design Process

The process of collaboratively working with colleagues, peers, and curriculum developers during the curriculum design process remains largely unexplored. In a review of the research examining teacher collaborative design (Voogt et al., 2011) notes:

> (H)ardly (any studies) examine the processes in collaborative design that promote teacher learning: the interaction with peers, facilitators and external stimuli, the experimentation in classroom practice, and the factors in the environment that hinder or facilitate teachers' collaborative design. (p. 1236)

Voogt's review yielded nine empirical studies, out of a possible 492 articles initially retrieved. The criteria for the search included the requirement to include empirical evidence, a produced curricular product, collaboration, and a reporting of the design process.

Creating a curriculum is a design problem. Design problems are ill-structured and wicked (Jonassen, 2000; 2011), largely because, "they have ambiguous specification of goals, no determined solution path, and the need to integrate multiple knowledge domains" (Jonassen, 2000; p. 80). Further describing why design problems are so ill-structured, (Goel & Pirolli, 1989) have characterized them as including, "many degrees of freedom in the problem statement, which consists only of goals and intentions, limited or delayed feedback from the world, artifacts as outputs that must function independently of the designer, and answers that tend to be neither right nor wrong, only better or worse" (p. 80). The creation of an artifact, a written curriculum, and the lack of clear evaluation standards for measuring the success or impact of a curriculum in a variety of classroom contexts, requires that teachers extensively explore a wide variety of problems that arise and create "symbol systems" (Goel & Pirolli, 1989) to deal with the challenge.

The necessity of being personally vested during the evaluation of a curriculum is also of significance in relation to curriculum design. The act of proposing a solution to a design problem becomes a task that is complicated and loaded with personal meaning. The end product, or curriculum artifact, is personally significant and meaningful given it is intended for use in classrooms beyond that of the designer. It encompasses more than a written plan for learning. Citing the work of Meacham and Emont (1989), Jonassen (2000) notes that ill-structured problems, "Often require learners to make judgments and express personal opinions or belief about the problem, so ill-structured problems are uniquely human interpersonal activities" (p. 67). Solving the problem of designing curriculum can and should rightly be viewed as a design problem, that requires a designer, or teacher, to be skilled in the process of solving problems. Developing a teachers pedagogical design capacity (Brown, 2009) has been advocated for as it relates to all aspects of curriculum design, from creation to implementation; but the research base specifically exploring how teachers strategize to solve problems during the curriculum design process are currently not available.

Reflection and curriculum design. As teachers are immersed in the curriculum design process and address curricular issues, “their understanding of the design problem evolves as the material is brought to life through talk. As an image of the problem (and solution) takes shape, a collaborative problem space (Jonassen 2000) emerges” (Boschman et al., 2014) (p. 413). (Hong & Choi, 2011) have developed a conceptual framework for designers to use when they encounter a design problem such as curriculum design via reflection. The framework is, "intended to guide educators and instructional designers in designing a learning environment that could promote reflection in novice designers while they perform design tasks in any domain” (Hong & Choi, 2011; p. 688). The framework is built upon the writings of Dewey (1933) and Schön (1983; 1987) and consists of three dimensions: (1) *timing of reflection*, (2) *objects of reflection*, and (3) *levels of reflection*. Each dimension of the framework represents a variety of reflection that can be acted upon when purposeful reflection is initiated to solve a problem, something that teachers may encounter during the curriculum design process.

Research on Curriculum Design Conversations

Focusing more closely on the specifics of team conversations allows for a more in-depth look at the types of paths chosen by designers and the expertise needed to be successful during curriculum design. A review of four studies focused on design conversations can offer more insight into the influences, decision-making strategies, and solutions sought when encountering a design problem.

Edelman and Liefer (2012) closely examined the path determination (“navigation” or “way-finding”) of 4 teams of undergraduate design students in a laboratory setting. The purpose of the study was to explore how the, "shared media (a designer) enlists shapes their conversations, and hence the development of new products" (Edelman & Liefer, 2012; p. 155). Each team was given 30 minutes, presented with identical media, audio and video recorded, and given space and materials to take on the redesign task. Analysis of each team revealed a "navigation" strategy that was put into place during the design process. The study also reported the occurrence of "radical breaks" (Edelman & Liefer, 2012) as teams would take off in inexplicable directions during the design process. Edelman and Liefer (2012) declared this strategy as one of "way-finding" and defined it as, "a set of nuanced behaviors that require fine tuning of perceptual abilities" (p. 180) which can be taught just as the analytical abilities of "navigation" had been taught to the design participants in this study during their undergraduate design courses.

Huizinga, et al.'s (2014) work with a small number of teachers (n=6) and facilitators (n=6) builds upon the division of design expertise, *generic* and *specific*, based on a review of the literature on design expertise (Huizinga, 2009). "Generic design expertise" (Huizinga, 2009) consists of inter and intra-personal skills coupled with process-related skills not directly related to the design task (e.g. organizational competencies). "Specific design expertise" (Huizinga, 2009) relates directly activities and skills needed to engage in the process of curriculum design. *Specific design expertise* is further broken into four categories (*curriculum design expertise*, *subject matter knowledge*, *pedagogical content knowledge*, and *curriculum consistency expertise*) two of which warrant further definition. *Curriculum design expertise* is further defined as requiring the following six skills: knowledge and skills to formulate a problem statement, idea generation skills, systematic curriculum design skills, formative and summative evaluation skills, curricular decision-making skills, implementation management skills (Huizinga, 2009). *Curriculum consistency expertise* is two-dimensional: internal or externally. The first relates to a curriculum's alignment within the members of the team and their perceptions of what is best for their students. External consistency is described as having congruence of curriculum's vision and purpose with members outside the team such as administrators or policy officials. Huizinga et al.'s (2014) study, which included interviews, not recorded design conversations, concluded that teachers need support in the areas of curriculum design expertise, pedagogical content knowledge, and curricular consistency. More specifically, teachers needed help formulating a problem statement and evaluation activities aimed at addressing problems as they arise. In addition to advocating that teachers' curriculum design expertise be further supported and developed, the study also recommended that support for teachers during the design process be provided, "just-in-time as an integrated part of the design process" (Huizinga, 2014; p. 53). Lastly the study reports that future research should, "examine more closely how support is designed and offered in real-time during collaborative design processes, if and how the current guidelines are applied, and how support affects teachers' design expertise" (Huizinga et al., 2014; p. 54).

George and Lubben (2002) reported on a four-day, teacher PD experience that involved two separate groups of 10 science teachers developing learning resources for their own classroom with a focus on context-based science teaching. The study, based in

Trinidad and Tobago, included transcribed audio and follow-up analysis of teacher and facilitator talk during curriculum design. Using a grounded theory methodology (Glaser & Straus, 1967) and open-coding analysis strategies, George and Lubben (2002) reported that, "although the student remained at the center of the teachers' focus, students' interests, and not their deficiencies, gained prominence as the workshop progressed" (p. 669) indicating a form of growth during the design process. They also reported on teacher concerns related to standardized testing noting that, "terminal examinations always lurked in the background" (George & Lubben; p. 670).

Boschman et al. (2014) recently reported on a small (n=9) multiple holistic case study utilizing three teams of kindergarten teachers' design conversations as the unit of analysis. The study coded design conversations using (Walker, 1971) (1971) classic study and categorization of educational design conversations which included brainstorming, issues, reports and explication. The purpose of the study was to, "understand whether and how teachers' existing orientations, external priorities and/or practical concerns influenced their conversations and decision-making" (p. 412). Utilizing the research on explicated design reasoning, they created a conceptual framework with three factors that influence design interactions of groups of teachers. The three factors used to frame the analysis were:

(a) existing orientations (knowledge, beliefs and practices);

(b) external priorities (what priorities from external stakeholders have to be addressed),

> and (c) practical concerns (what is feasible and reachable in practice, how to orchestrate learning activity). ((Boschman et al., 2014); p. 395)

Practical concerns as reported on by Boschman et al. (2014) were found to be in accordance with Doyle and Ponder's (1977) "teacher practicality ethic" that states teachers must consider the instrumentality, congruence, and cost associated with considering the inclusion of a proposed innovation into their classroom. Boschman et al. (2014) also noted that beginning with teacher's existing orientations or identity (Spillane, 2000) can serve as a teacher's precedent, "to help teachers recognize the design problem and find solutions that seem trusted and feasible" (p. 413). Lastly, the study found that when teachers encountered a problem during the design process, the problem was not sufficiently analyzed. Instead, teachers quite often participated in brainstorming sessions to find a solution to the problem they were facing.

Overall, this section detailed some examples from the research concerning team-based, curriculum design. The section did not significantly detail how specific supports or assistance can impact teachers during curriculum design.

Coaching Supports

Providing coaching supports to teachers during the design process stems from the research base involving purposeful and meaningful reflection. Coaching, whether it is cognitive, content, or instructional, is a form of guided reflection built on the writings and research of Dewey (1933) and Schön (1983; 1987). As Schön notes:

> The student cannot be taught what he needs to know, but he can be coached; he has to see on his own behalf and in his own way the relations between

> means and methods employed and results achieved. Nobody else can see for him, and he can't see just by being "told," although the right kind of telling may guide his seeing and thus help him see what he needs to see. (p. 14)

Given the role of a coach in the teacher curriculum design groups used in this study, a closer look at varying methods of coaching practices is justified. Cognitive coaching (Costa & Garmston, 2002) focuses on teacher learning by providing partner to help clarify a teacher's thoughts and perceptions of a given situation, with the end goal of helping the teacher determine a path of action and assessment for achieving that goal. A cognitive coach takes on the role of mediator, more so than a partner. Content-focused coaching (West & Staub, 2003) explores and develops the development of a teacher's content knowledge, pedagogical content knowledge, and underlying beliefs about teaching and learning, with the specific goal of addressing student content learning. Aspects of cognitive coaching and content-focused coaching are both utilized in instructional coaching and reflective practice coaching.

Partnership is a role more representative of an instructional coach (Knight, 2007; 2009). Instructional coaching takes on similar approaches to cognitive coaching (e.g. paraphrasing, questioning, and understanding) with the added dimension of partnership and relationship. As Knight (2007) states, "how well a person connects or fails to connect emotionally with others profoundly affects the quality of relationships that person experiences" (p. 79). The seven principles of instructional coaching: equality, choice, voice, dialogue, reflection, praxis, and reciprocity (Knight, 2007) form the foundation of theory and practice of instructional coaching. This philosophical difference is slight, but noticeable when examining coaches espousing different theoretical foundations. A hybrid of instructional and cognitive coaching that aligns more closely with instructional coaching is reflective practice.

Reflective practice, furthered by York-Barr, Sommers, Ghere, and Montie (2006) is built upon the work of among others, Killion and Todnem (1991). Killion and Todnem (1991) ascribe that reflective practice is, “the act of analyzing our actions, decisions, or products by focusing on our process of achieving them” (p. 15). York-Barr et al. (2006) further define reflective practice with partners, "to refer to two or three people (dyads or triads) who collaboratively engage in a reflective learning process focused on improving educational practice, with the ultimate objective of enhanced student learning” (p. 108). Reflective practice or coaching, is, “predicated on adult learning principles that emphasize the need for development to be relevant to and embedded in practice, supported by collaboration among peers, and approached as a continuous and intentional process” (York-Barr et al., 2006; p. 120).

The act of introducing multiple individuals to a coaching situation, as opposed to one-on-one coaching, further complicates the role of a coach. As Osterman and Kottkamp (1993) state, “the facilitator must be skilled at developing an environment in which the participants feel comfortable enough to contribute actively (safety) and an environment in which they have the opportunity to participate (equity)” (p. 63). A coach needing to facilitate a team-based, reflective conversation must attend to planning what will happen before the conversation, react and respond to what happens during the conversation. A coach must also aim to create, "constructive dialogue, (while) viewing issues and events from different perspectives, generating ideas, solving problems, managing and learning from conflict, and making decisions" (York-Barr et al., 2006; p. 159). This design work and "on the spot" interpretation, reflection, and spontaneity requires a great deal of focus, understanding, and attention to the task at hand. Not only must a coach interpret and analyze each member of the team's participation, feelings, responses, and engagement, they must also attend to their own positioning and influence in and on the group.

Power, positions, and roles in coaching. Davies and Harre (1990) view positioning as a conversational reality where power and influence continually shifts, in varying contexts and by varying individuals. This type of post-structuralist perspective on power has been explored in the realms of coaching, primarily in the worlds of literacy coaches and elementary teachers. Rainville and Jones (2008) reporting on the dissertation work of Raniville (2007) report the findings of one of the first empirical studies of literacy coaches. Rainville and Jones (2008) note that, "Conscious and strategic self-positioning by a coach as a learner or co-participant is not only possible but also can open up spaces in which teachers feel they can take control of their professional development and experiment with ideas that could change their practices" (p. 447). In another study examining the types of positioning and roles coaches and teachers bring into a coaching conversation (Ortmann & Roehrig, in review) reported on the impact of well-established teaching identities as it relates to roles and position during STEM-focused coaching conversations. As should be expected, team reflection in groups of 3 or 4 present opportunities for learning and inherent challenges for a coach, and the individuals involved in the conversation. Members of the team may develop expectations and assumptions about what should be occurring during the team's time together and who should take on specific responsibilities. As Fullan (2001) warns:

> "Group expectations are the unspoken assumption about how people behave and interact in a particular group context. Over time, expectations become constraints. Members assume expected roles and offer anticipated responses. Attempts to change or adjust these expectations are often punished or ignored, resulting in groups becoming stuck. Change is needed but rarely initiated. Going along to get along sometimes keeps us from confronting issues. It is easier to ride the horse in the direction it is going, even if that direction is off course" (p. 154).

Given the small, but growing research base involving coaching, power and position, specifically as it relates to science, it is necessary to draw on research in the area of literacy coaching. Ippolitto (2010) investigated the work of 24 literacy coaches located within a single school district by conducting interviews (individual and focus group) and observing 8 teacher-coach meetings during the spring of the 2007-08 school year. Ippolitto (2010) reported on the occurrence of tensions amongst the coaches as they attempted to balance the varying influences that their coaching meetings involved. Coaches in the study moved between directive and responsive coaching moves to alleviate this tension and also developed three key strategies aimed at alleviating these tensions. Ippolitto (2010) notes the following ways that coaches fostered collective learning with their partner teachers:

> (1) shifting between responsive and directive moves within a single coaching session; (2) using protocols to guide individual and group coaching sessions;

> and (3) sharing leadership roles to align teacher, coach, and administrative goals. (p. 184)

Other studies have reported on the success of coaches providing support of this nature to teachers aimed at improving their practice (e.g. Vogt et al., 2011). Coaches can be mentors (Davis & Varma, 2008), graduate students (Hunter, 2009; Pickering, 2013), or professional engineers (Pinnell et al., 2013). As the use of coaching expands to other disciplinary areas outside of literacy, the research base needs to grow and develop. Content-specific coaching in the fields of math and science are limited primarily to case studies (Mudzimiri, Burroughs, Luebeck, Sutton, & Yopp, 2014); DeChenne et al., 2014), a news article (Bransfield & Nastasi, 2007), a dissertation (Kraus, 2008), and a study over 25 years old (Tobin & Espinet, 1989).

DeChenne et al. (2014) followed seven coaches from one district, with the goal of better understanding coaching and the coaching process of teachers involved in a ten-day, summer PD. The goal of the PD was to, "develop and implement a guided inquiry lesson that used the engineering context to teach a science or math concept" (DeChenne et al., 2014; p. 7). Data collected included lesson plans, teacher classroom implementation of the teacher-developed lesson plans, and interviews. The small sample size and minimal contact time between teachers and coaches (limited to 10 days of PD) warrants that the findings of the study not be considered generalizable or transferable; however given the limited research on coaching in science or math, it's worth noting some of the study's findings. DeChenne et al. (2014) report that it is important to have a content match between teachers and coaches and that coaches not serve in supervisory roles in addition to their coaching responsibilities.

(Mudzimiri et al., 2014) closely examined the roles and interpersonal dynamics of seven mathematics coaches from five districts. Researchers used a questionnaire and a “shadowing” technique that involved the use of a template, which observers would use to record observations of coaching activities in 15-minute intervals. (Mudzimiri et al., 2014)’s analysis revealed three strategies utilized by coaches in the study: relational strategies, exchange of information instances, and facilitative strategies aimed at promoting teacher learning. The findings of the study again are limited by the small sample size and limited amount of data collected (each coach was observed for one day). (Mudzimiri et al., 2014) report that quite often coaches must work “in the moment” and are often viewed as being the expert in a hierarchal relationship with the teacher. Ultimately, the research suggests that further empirical studies are needed to better understand the effectiveness of mathematics coaching.

Coaching during curriculum design. There is limited research that provides specific suggestions for coaches working with teachers during the curriculum design process (Huizinga et al., 2014.). There is one aspect of coaching that connects well with curriculum design that is beginning to take shape in the literature. A series of researchers (Remillard, 2005; Davis & Krajcik, 2005; Handelzalts, 2009) have begun to advocate for productive and meaningful conversations about a curriculum’s purpose, promises, and intent as a valuable strategy for fostering a teacher’s curriculum design expertise. As Remillard (2005) claims, it would be beneficial for teachers to, “examine a new curriculum with colleagues, making their interpretations and decisions explicit to themselves and others. A central goal of such an activity would be for teachers to openly and actively engage in participating with a curriculum" (p. 240). As Remillard (2005) states, interactions of this nature "respond directly to the curriculum as a subjective scheme" (p 229) by directly addressing the teacher-curriculum relationship. Remillard (2005) claims that a, "teacher's perception of and stance toward curriculum materials and the teacher's professional identity as it relates to the use of curriculum resources" (p. 228) are revealed and connected when this occurs.

The need to pay attention to what is occurring during curriculum design conversations as a coach is highlighted when curriculum conceptualization occurs. It is important to pay attention to what teachers are saying, and what they are suggesting because as Kerr (1981) notes:

> there are some serious discrepancies between the ways we teach educators to think as designers and the ways they would proceed if left to themselves. Obviously, we cannot assume that these naturalistic design practices are what teachers should be doing simply because they are what teachers are doing. (p. 375)

For example, it is very likely for teachers to be highly influenced by the materials that will be used when a curriculum is implemented (Joyce, 1978; Kerr, 1981; Taylor, 1980). That is, teachers work from the materials, not towards them A coach who is aware of this tendency will be in a better position to help teachers identify important aspect of the design, from the view of a designer as well as a teacher.

Finally, it is worth noting that specific models for coaching, curriculum design, and STEM integration are not currently available, although there are those who have advocated for such a model (Ortmann & Roehrig, in review). The development of more conceptualized models will arise as reform efforts continue to impact what happen inside and outside of science classrooms.

Curriculum Needs Related to Recent Reforms

The inclusion of integrated STEM experiences in K-12 classrooms will continue to be advocated for by national policy and national science standards as a means to drive economic development and ensure national security (NRC, 2011; 2012; 2014). The importance of understanding the connection between intended and enacted classroom curriculum and the teachers who take up this task will also continue to be important. Just as the National Academy of Science (1988) declared over 25 years ago, "curricula still matter. By providing materials, encouragement, points of view, evaluations, and other pressures for certain approaches to teaching and learning, as well as discouragement and sanctions for others, curricula shape behavior" (p. 119). Reforms advocate that school districts ensure their STEM curriculum be "rigorous" and articulated around a "sequence of topics and performance" (NRC, 2013). To endorse change and succeed where previous reform efforts in science education have failed, curriculum materials must play a vital role (Powell & Anderson, 2002).

Integrating engineering into curriculum. Engineering standards and standards-based curriculum development will continue to appear in state science, math, and technology standards (CARR, BENNETT, & STROBEL, 2012; Moore, Glancy, & Tank, 2014). In a review of over 30 curriculums in the past 20 years, the NAE (2009) conducted a survey of the landscape of engineering education. The implications of this review indicated that teachers are taking up the call to integrate engineering into their classrooms; however, the typical approach is to implement a pre-designed curriculum (e.g. Project Lead the Way, A World in Motion, and Engineering is Elementary [EiE]). Increased integration will be dependent on many factors, including the attainment of the needed materials and resources to enact an engineering-focused curriculum (Moore, Stohlmann, Wang, Tank, & Roehrig, in press).

In a paper outlining the necessary vision needed to accomplish the integration of engineering into K-12 classroom in the U.S., Bybee (2010) asserts that the first step lies in designing, developing, and implementing model STEM units in traditional science or mathematics classrooms. These new STEM units would stress competencies as learning outcomes, and would use the contexts of engineering challenges, as themes in which teaching and learning would occur. Students would then apply scientific understandings to design a solution to the design challenge while also using mathematical concepts to enforce science learning while gaining a better understanding of the engineering design process.

Integrated curriculum learning experiences. The NGSS (NGSS Lead States, 2013) which were designed around the Framework (NRC, 2012) recommend that instruction be tailored around "bundles" of performance expectations:

> Curriculum and instruction should be focused on "bundles" of performance expectations to provide a contextual learning experience for students. Students

> should not be presented with instruction leading to one performance expectation in isolation; rather, bundles of performances provide a greater coherence and efficiency of instructional time. These bundles also allow students to see the connected nature of science and the practices. (p. 6)

The hope of the Framework and NGSS is that science education will move in a new, integrated and authentic direction with curriculum resources that “provide(s) students with engaging opportunities to experience how science is actually done” and does not involve the teaching of “discrete facts with a focus on breadth over depth,” (NRC, 2012; p. 1).

The NRC (2014) has put forth four recommendations for designers of STEM integrated learning experiences advocating that, “Programs that prepare people to deliver integrated STEM instruction need to provide experiences … (and) …training to work collaboratively with their colleagues” (p. 9). The task of creating integrated learning experiences does not fall squarely on the shoulders of teachers, but rather all those vested in science education including the research community. The NRC (2014) has indicated that research investigations are needed into STEM integration, noting that, “researchers should be explicit about the nature of the integration, the types of scaffolds and instructional designs used, and the type of evidence collected to demonstrate whether the goals of the intervention were achieved” (p. 9). This study’s overall research design and analysis strategy aligns well with this recommendation.

Chapter III: Research Design and Methodology

The following chapter outlines the study's research design. After briefly restating the purpose of the study, a rationale for the design of the research will be discussed. Next, details associated with the research design will be explained and aligned within the research plan: context of the study, sampling procedure, data collection, and data analysis. Lastly, a discussion of the reliability, trustworthiness, and validity will be discussed.

Purpose

This study is primarily intended to explore the curriculum design process of elementary science teachers tasked with integrating STEM into their elementary classroom. The study aims to provide insights into the following phenomenon: (1) The curriculum design actions of teachers focused on STEM integration (2) The negotiation of roles as exhibited by teams of teachers and coaches during the curriculum design process. (3) The pronounced and hidden drivers that influence teachers' design decisions while they design curriculum focused on STEM integration.

Research Questions

The overarching research question for this applied, qualitative research study is: *How do teachers engage in the curriculum design process in collaborative teams while co-developing a curricular unit focused on STEM integration for their classrooms?* The supplemental research questions that will support this overarching research question are:

1. What are the intuitive and orchestrated curriculum design practices of science teachers and coaches while they co-design a curricular unit focused on STEM integration?

2. How do science teachers and coaches negotiate their roles as curriculum designers in a collaborative team while creating a curricular unit focused on STEM integration?

3. How do coaches view and enact their roles as mediators and collaborators while co-developing a curricular unit focused on STEM integration with science teachers?

4. What influences predominately impact and influence a curriculum design team's decisions during the creation of a curricular unit focused on STEM integration?

Rationale for Research Design and Analysis

Case study research. The qualitative nature of the study deemed that a case study methodology with inductive analysis and creative synthesis be employed. Merriam (2009) defines a case study as, "an in-depth description and analysis of a bounded system" (p. 43). The justification of what counts as a case study according to Merriam (2009) is the intrinsically bounded nature of a particular case, with its defining nature being the unit of analysis. Merriam (2009) goes on further to describe the product of case study research as, "an intensive, holistic description and analysis, of a single entity, phenomenon, or social unit. Case studies are particularistic, descriptive, and heuristic" (p. 46). The bounded case, and unit of analysis for this study were the experiences of three teams of 12 elementary science teachers and three graduate student coaches during a 12-day PD opportunity centered on curriculum design. The perspectives and experiences of this group of teachers and coaches was the primary focus of the study in addition to supplementary, contextual data from the PD itself. Empirical data gathered in a qualitative endeavor of this nature strive to provide "thick descriptions" (Geertz, 1973) in an attempt to theorize about the social conditions of contextualized, historical, and social phenomenon (Alasuutari, 1996).

Analysis strategy. The study employed the analysis strategies of constructed grounded theory (Charmaz, 2006) that is built on the works of Glaser and Straus's "grounded theory" (1967; Glaser, 1978; Strauss, 1987). Glaser and Straus (1967) in describing the generative nature of grounded theory state that, "Generating a theory from data means that most hypotheses and concepts not only come from the data, but are systematically worked out in relation to the data during the course of the research" (p. 6). This study applied Glaser and Strauss's (1967) commonly used analysis strategy of constant comparative methods that is founded on this underlying principle. That said, grounded theory methods have been exposed to challenges and transformations since being introduced, which have allowed for more interpretive and explanatory uses of its analysis strategies. Grounded theory as described by Charmaz (2006) is characterized as having, "a close fit with the data, usefulness, conceptual density, durability over time, modifiability, and explanatory power" (p. 6). The delimitation of constructed grounded theory places emphasis on an inductive strategy of theory development (Charmaz, 2006). In opposition to positivism and its emphasis on variable causality, Charmaz (2000) points out that causality in constructed grounded theory, “is suggestive, incomplete, and indeterminate. … it looks at how ‘variables’ are grounded —given meaning and played out in subjects’ lives — … Their meanings and actions take priority over researchers’ analytic interests and methodological technology” (p. 524). Analysis strategies in constructed ground theory are, “a set of principles and practices, (and) not (seen) as prescriptions or packages” (Charmaz, 2006; p. 9). The view of grounded theory method taken up in this study echoes the works of Charmaz (2000; 2002; 2006) and others who have also developed an interpretive view of grounded theory analysis strategies (Bryant, 2002; Clark, 2003). The nature of the research study justified the use of a case study methodology as described by Merriam (2009), couple with the systematic data analysis strategies and techniques of constructed grounded theory as described by Charmaz (2006).

Qualitative research helps in providing answers to “how” and “why” questions when interventions or new frameworks are introduced. Namely, it responds well at discovering how interventions worked differently in different contexts and can be used to eliminate alternative explanations (NRC, 2002). The instrument or tool used in qualitative research of this nature is the researcher. As the primary research instrument in this study I was continually involved in reflection, interpretation, and re-interpretation of the observations being made and the data being collected during the 12 days of curriculum development and following months of analysis. In regards to curriculum research, Smith (1983) asserts:

> (G)iven its inherently complex and creative nature, its interpretive goal … and the progressive breadth of concerns combined with the consistent need for sensitivity to new findings and insights, curriculum research requires qualitative methodologies and openness to emergent findings throughout the phases. (as cited in Clements, 2007; p. 58)

Context of the Study

Professional development description. The scope of this study was limited to the 12 days of PD that occurred during the months of June and July in 2014. There were 40 teachers (grades 4-8) who were recruited and voluntarily registered as ‘fellows’ during year 2 of the project. Teachers in the study came from one of four partnership school districts within a major, metropolitan area in the Midwest. Thirty of these teachers were returning fellows from the inaugural year of the project. Other individuals present during the 12 days of PD included: 13 graduate students that took on the role of coaches for a team of teachers, three administrative staff, five principal investigators associated with the project, two cooperating scientists, and two cooperating engineers. The professional development experience primarily took place at a continuing education center on the campus of a large, Midwestern university.

The PD experience, hereby referred to as *EngrTEAMS* (pronounced “engineering teams”), provided teachers in grades 4 thru 8 with the opportunity to develop and create an integrated STEM curriculum for their elementary or middle school classrooms, prior to the upcoming 2014-15 academic year. A primary goal of the project was to promote curricular design that allows content to be taught more meaningfully in the same or less time as more standard ways of approaching the teaching of science. The STEM integration model advanced during the PD followed the framework of Moore et al. (2014) and stressed the following key indicators from the framework: *process of design*, *apply science engineering and mathematics*, *teamwork*, and *communication related to engineering*.

As part of this project participant teachers were asked to develop a STEM-integrated curricula based on relevant state science and math standards in small teams intended for use in their classrooms with the intention to also disseminate the curricular units after a three stage development process (development, pilot, and implementation). The data collected for this study occurred during the first stage of this process. The pilot stage gave teachers the opportunity to test and try the activities they were co-developing with a group of kids from a local youth camp. This middle stage also occurred during the summer, prior to the start of the 2014-15 academic school year and after the first stage. A general sequence and summary of the first stage and the 12 days of PD can be found in Table 3.1.

The PD contained workshop sessions that involved the following topics: (1) engineering design, data analysis and measurement (2) science-specific content (earth, physical, life), (3) engineering pedagogies (4) curriculum writing. The curriculum writing process was guided by Wiggins and McTighe's (1998; 2011) *Understanding by Design* [UbD] framework for creating curricular units. The UbD framework navigates teachers through the curriculum design process by employing a "backwards design" model that first begins with identifying the desired results of a unit that are derived from state standards. Understanding by Design has been advocated for by Penuel et al. (2008) who note, “The act of planning, enacting, and revising curricular units engages teachers more deeply with their teaching, so that they can come to understand more fully the principles of effective curriculum” (p. 418).

During day 3 of the PD, teachers were asked to choose one of three content area focuses: earth, life, or physical science. The focus of the professional development involved the creation of a content specific (earth, life, or physical science) STEM-integrated curricular unit with an emphasis on creating an engineering design challenge to occur at the culmination of a seven to ten day teaching unit. Each team of teachers was assigned a coach to work with the group during the development of the STEM-integrated unit. Graduate students, or “coaches” as they will hereby be referred to were PhD-track graduate student (STEM Education) who previously participated in 2 graduate-level courses. The first course was focused on STEM and STEM integration and was lead by three of the co-principal investigators of the project. The second course and associated follow-up training sessions were focused on specific coaching methodologies aimed at helping teachers cultivate their skills as curriculum developers and STEM teachers via reflective practice (York-Barr, Sommers, & Ghere, 2006). The coaching model was instituted as a support for on-going and just-in-time support for teachers as they design, implement, and revise their respective curricular units.

Table 3.1: EngrTEAMS major PD activities including curriculum design.

Day	1	2	3	4
Major Activities	- Project Introduction - STEM Framework - "Make it Better" (MiB) Activities - Teamwork Strategies - Introduction to Integration Curriculum Assessment (ICA)	- Communication Activity - Data Measure/Analysis Strategies - Introduction to Process of Design - Model Eliciting Activity (MEA)	- Content Groups Split (Earth, Life, Physical) - Simple Machines Activity (Bikes) - Data Analysis/Visualization - Understanding by Design (UbD) Introduction	- Teams Form (Teachers/Coaches) - Motion in 1 Direction - Science Simulations - Data Analysis Activity - Standards Unwrapping (UbD) - Girl-Friendly Physics
Day	5	6	7	8
Major Activities	- Forces Activity - Continued UbD - Hover Craft Activity - Application of Science ad Math in Design Challenge	- Team Curriculum Design Time - Required Generation of 3 Possible Unit Ideas - Design Challenge Example "Push it to the Limit"	- Curriculum Idea Inter-Team Share Out - Team Curriculum Design Time: Idea Generation - Team Curriculum Design Time: Idea Evaluations	- Team Curriculum Design Time: Content Standards Consideration - Team Curriculum Design Time: Idea Sharing (engineers, scientists, coaches)
	9	10	11	12
Major Activities	- Team Curriculum Design Time: Lesson Plan Considerations - Team Curriculum Design Time: Contexts for Unit	- Team Curriculum Design Time: Feeling the Pressure	- Last Day before 4th of July Break - ICA Check of Curriculum - Team Curriculum Design Time	- New Location - Two Alternative Dates - Team Curriculum Design Time

Sampling procedure. The process of choosing 12 teachers, from a potential pool of 40 was accomplished by using a purposeful sampling strategy (Patton, 2002). Patton (2002) supports purposeful sampling as a process of, "selecting *information-rich* cases for study in depth. Information-rich cases are those from which one can learn a great deal about issues of central importance to the purpose of the inquiry" (p. 230). The primary participants for the study were three collaborative teams of teachers, each paired with a single coach. It was pre-determined to not involve any teachers directly working with the researcher (see researcher's role below) during the earth science breakout section of the PD. This initial prerequisite eliminated 11 potential teachers. The pool of teachers interested in integrated life science content standards into their curriculum was also not selected due to a potential disconnect between engineering standards and life science standards. This left a potential pool of 17 teachers, 12 of who were purposefully selected based upon coaching matchups, prior relationships with teachers in each of the selected teams, and suggestions from the co-principal investigator who selected the coach/teacher team pairings. Descriptions and information regarding each team and individual teacher will be presented in Chapter IV.

Data Collection

The primary source of data collected for this study was the design conversation carried out by teams during the curriculum design process. The other major data source for the study was individual teacher and coach interviews conducted towards the end of the PD (Days 9-11). Supplemental data sources were used to support the conversations that occur during curriculum design and will further be discussed below.

Curriculum design conversations. The last seven days of the PD were predominantly dedicated to team curriculum design (see 3.1). Team curriculum design time was considered "open-time" for the teams and coaches to develop and write their curricular units. Curriculum design conversations varied in content and form over the span of the PD and will be reported on in the results section. To collect curriculum design conversations, each coach was given a digital audio recorder to place on the table during team conversations about the curriculum. In an attempt to gain access to formal and informal conversations that may not be collected by a digital audio recorder placed on a table, a "tie-clip" microphone attached to a digital audio recorder was worn by four of the 12 teachers.

Collection, categorization, and transcription of curriculum design conversations was conducted in the following manner: (1) all audio-recorded conversations were uploaded by the participating coach to a secure, online server (2) audio .mp3 files were filed using a pre-determined naming system (name, date, time, etc.) (3) audio-recorded files were then copied onto the researcher's computer from the online server (4) these files were then uploaded to a software transcription tool (5) audio files were then listened to by the researcher, with select turns[1] being transcribed using Jefferson transcription conventions[2] (6) the newly created text-based document and associated audio file were then uploaded to a data management software program (NVivo Qualitative Data Analysis

[1] Select turns: Audio files ranged in length from less than 10 minutes to greater than 200 minutes. Given the amount of time required to transcribe real-time, uninterrupted conversations amongst 3 or more individuals, all speech utterances were not transcribed. The researcher's own subjectivity and experiences facilitating curriculum design conversations determined which turns and series of turns were transcribed. Conversations deemed less pertinent, were documented in the transcript with a mark of time lapsed between transcribed turns, and a sentence summarizing the incident.

[2] Transcription conventions are adapted from the Jefferson system. The format of the conventions table was modeled on one used in Majors (2007).

Software, 2014) where they were classified again by time, date, and team (7) all transcripts were then analyzed via incident-by-incident or line-by-line initial coding (Charmaz, 2006). A description of the coding process and subsequent analysis procedures will be discussed in the analysis section.

Individual interviews. Individual interviews were carried out on days 9-10 when the teachers were actively involved in the process of curriculum design. Each participating teacher and coach was interviewed. Interviews ranged from 35 minutes to 60 minutes. All individual interviews were audio-recorded using a digital audio recorder and transcribed for later analysis. The semi-structured interview protocol (Appendix A) was developed based on recommendations from Charmaz's (2006) call for "intensive interviewing" (p. 25) while also being informed by the works of Rapley's (2001) "open-ended interviewing" strategies (p. 39) and Garton and Coplands' (2010) discussions of the effects of prior relationships during one-on-one interviews. The content of the questions aimed to gain insights into the curriculum design process of collaborative teams, while also exploring the perceived barriers and supports that may arise during the process. The open-ended nature of the interview questions aligned with the overall research design. As Charmaz (2006) states:

> By creating open-ended, non-judgmental questions, you encourage unanticipated statements and stories to emerge. The combination of how you construct the questions and conduct the interview shapes how well you achieve a balance between making the interview open-ended and focusing on significant statements. (p. 26)

Written participant reflections. To gain access to individual thoughts, feelings, and experiences, individual reflections (paper-based and digital) were collected via a series of reflective prompts (Appendix A). Time for participant reflections was allocated for in the PD and was administered and collected at the end of the day. Reflections were not mandatory.

Professional development media: Field notes, audio/video, handouts, and pictures. In taking on the role as a participant observer (Patton, 2002), the researcher collected descriptive field notes (Merriam, 1998) before, during, and after workshop sessions during seven of the 12 days. Teachers were engaged in a variety of PD sessions revolving around the project's goals (e.g. engineering design pedagogies, science content, math pedagogies) and it was deemed necessary to collect this additional layer of data as a secondary source. Patton (2002) specifies field notes as containing, "your insights, interpretations, beginning analyses, and working hypotheses about what is happening in the setting and what it means" (p. 304). As a reference for later analysis to complement the researchers' field notes, digital audio recordings and select pictures of all workshop sessions were collected to gain background information about PD sessions that potentially impacted curriculum design conversations. The researcher was unable to attend days 3-6 of the physical science-focused PD due to his involvement in the earth science-focused PD. During these 4 days, the facilitators of the PD video-recorded all sessions for later analysis, which took the form of researcher field notes that summarized PD events, discussions, and activities. Select audio and video of instances where the teachers were addressed as a whole were also transcribed and used as a secondary data source. A supplementary data source related to the PD that was also collected included PD handouts (frameworks, readings, books) and binders containing standards, test specs, and information overviewing the project.

Reflexive audio journal. The interpretive nature of the study dictated that the researcher to keep and maintain a daily audio reflective journal during the 12 days of the PD. Insights spurred by reflection can be of value when rediscovering collected data at a later time. As Dewey (1938) claims there are, "periods of genuine reflection (that) only occur when they follow after times of more overt action and are used to organize what has been gained in periods of activity in which the hands and other parts of the body beside the brain are used" (p. 27). Select audio reflections were also transcribed.

Curriculum design artifacts. Curriculum design artifacts were digital and non-digital, teacher or coach-created documents that included: lesson plans, "brainstorming" documents, documents containing links to online resources, curriculum development related documents (e.g. UbD documents), content standards that were unwrapped to create "big ideas" or "essential questions". All 3 groups readily used Google Docs to create, share, and save these digital artifacts. The use of Google Docs also allowed for the researcher to time-stamp and identify when and which member of the team contributed to a particular document. Non-digital artifacts included team-created posters that were displayed around a team's workspace. Other non-digital artifacts included hand-written documents that teachers created in individual notebooks. All non-digital artifacts were recorded using a digital camcorder and stored for later analysis.

Data Analysis

In searching for themes and patterns in the data during analysis, an inductive analysis with creative synthesis was employed (Patton, 2002). This analysis was guided by the process of constructed grounded theory as described by Charmaz (2006). In essence, as Ellingson (2009) points out, the study, "presupposes that no truth exists 'out there' to discover or get close to, but only multiple and partial truths that researchers (and others) co-construct" (p. 22).

The data sources that were collected for this study were "triangulated" (Fielding & Fielding, 1986) to, "reduce the risk that conclusions will reflect only the systematic biases or limitations of a specific source or method" by allowing a researcher to, "gain a broader and more secure understanding of the issues you are investigating" (Maxwell, 2005, p. 93). The use of a data analysis software program was employed to organize, code, and aid in the analysis of all collected data. Dey (1999) in support of data analysis software states that it, "provides a more diligent and disciplined approach to the auditing of the creative process" (p. 24; as cited in Charmaz & Bryant, 2007).

Coding design conversations. The defining feature of grounded theory analysis strategies is its inductive analytical process. The first analytic step is coding of the collected data. This interactive process is done not to make empirical observations of the world that are completely objective, but rather as Charmaz (2006) states, "we choose the words that constitute our codes. Thus we define what we see as significant in the data and describe what we think is happening" (p. 48). As Patton (2002) states, "Raw field notes and verbatim transcripts constitute the undigested complexity of reality. Simplifying and making sense out of that complexity constitutes the challenge of content analysis. Developing some manageable classification or coding scheme is the first step of analysis" (p. 463). This process is facilitated by asking yourself questions about the data, "what's interesting, why is it interesting, and why am I interested in that" (Bazely, 2007; p. 74). These questions resonate with Glaser's (1978) inductive analysis strategy of prompting the researcher to ask, "What is this data a study of?" (p. 57). Bazely (2007) goes on further to suggest that this process will, "lift you off the page to generate a more abstract and generally applicable concept, which, if relevant to your project, will be very worth of a node and memo" (p. 74). The process of "fracturing or slicing" data (Bazely, 2007) accompanied by a tagging and coding strategy, allows for future retrieval and a creative synthesis of the data that moves above and beyond each unique, individual team.

Initial coding. The open-ended nature of initial coding remains true to the works of Glaser and Strauss (1967) while realizing that the individual doing the coding has prior experiences and understandings that will influence this process. In relation to the process of creating initial codes, the previously mentioned works of Huizinga et al. (2009; 2014) and Voogt et al. (2011) were influential. Huizinga et al. (2014) deductively coded the interview responses of teachers and facilitators after engaging in the curriculum design process allowing for the creation of a framework that outlined broad categories that occur during the curriculum design process. Voogt et al. (2011) used Clarke and Hollingsworth's (2002) Interconnected Model of Professional Growth to analyze the process of teacher learning and development during the curricular design process. Each of these influences presents itself as a preconceived idea that may have influenced the initial coding process. However, “From the standpoint of grounded theory, each preconceived idea should earn its way into your analysis-including your own ideas from previous studies” (Charmaz, 2006; p. 68). Team design conversations and individual interviews were analyzed and initially coded inductively given these interceding influences.

During initial coding, the researcher would read, re-read, and examine the study’s research questions while thinking about each individual participant’s experience. In considering how each individual experienced the PD via individual interviews, participant reflections, pictures, and digital artifacts (e.g. brainstorming documents) multiple data points were considered when initially coding the data. This allowed for a more detailed view of each spoken phrase during the curriculum design process and individual interviews. Table 3.2 provides an overview of the total amount of filtered and transcribed minutes of design conversations and individual interviews. It also contains the total number of non-unique codes that were initially created. Recall that initial codes could be applied to as many incident-by-incident, or line-by-line exchanges as needed.

Table 3.2: Team design conversation times and coded incidents.

Team	Design Conversations Recorded (minutes)	Total, Non-unique Codes
1	1217	1496*
2	1175	554
3	935	472

*First team coded

Once a title or phrase for a specific code was determined, a short description of the researcher’s thinking during the creation of a code was also created, occasionally with example "in-vivo" excerpts taken directly from the transcripts. An example excerpt[3], initial code, and associated description can be found below.

- Susan: The friction…the surfaces will be designed to give different frictions and different states of matter. Then I'm thinking learning activities to gain background knowledge would be something like engineering a hovercraft. Just like we did before where it (the hovercraft) had to travel the furthest and straightest. And then we could add engineering a simple machine to lift a load.

This utterance during the design process was coded as "**Curriculum Design Process** – *background activity*". The description that was written upon creating the codes was, "an instance where the mentioning of providing a background activity for students to complete prior to taking on a design challenge". To allow for smooth transitions during the categorization of initial codes, a categorization system was put into place to allow for quick transitions between a transcript and tagging of the exchange. Initial codes fell into one of the following "top-level codes", depending on the team and the content of conversations: **Coach/Coaching**, **Curriculum Design Process**, **Curriculum Idea**, **STEM Curriculum Design**, **Professional Development**, **Teacher**, **Team**. These major categories were not preconceived, but rather emerged during the process of coding the initial team's conversations and interviews. Initial codes were then further sub-divided into hierarchal codes. For example, the top-level code **STEM Curriculum Design** was sub-categorized with the initial code *engineering design challenge*, a key component of a STEM-integrated curriculum. This initial code was then sub-divided into further initial codes, (e.g. redesign, feasibility, variables, content-knowledge, etc.) Each of these sub-

[3] Final display of all excerpts is displayed without transcription conventions.

categorized initial codes was inductively generated from the data. An example of an excerpt that was coded as **STEM Curriculum Design**, *engineering design challenge*, and lastly *content knowledge* follows:

- Sammy: How can we get…how can we make sure were requiring them (students) to do greater force will cause greater change in motion?

Here, Susan is asking a question about a proposed engineering design challenge and the applicability of the scientific content knowledge that students will need to complete the design challenge. Once a code was created, future incident-by-incident coding could result in the reapplication of a previously created code, or the creation an entirely new initial code. Incidents could be coded using one or more initial code.

Successive coding of the other two teams' design conversations and interviews were accomplished using the same strategy and by also allowing "constant comparative methods" (Glaser & Strauss, 1967) to be employed. Initial codes were juxtaposed against previous initial codes and extracts in search of comparison and distinction. This search for comparisons amongst the data, categories, and conceptual categories initiates the analytical process of grounded theory. The continuous process of interpreting, coding, comparing, and analyzing coded data gives grounded theory its analytical backbone. Table 3.3 gives a hierarchal overview of the resultant top-level, mid-level, and low-level codes. The study's theoretical assertions conceptual categories will be presented in Chapter IV.

Table 3.3: Example hierarchal orders of coding process.

Top-Level Code	Mid-Level Codes	Low-Level Codes
Coach	Questioning, Uncertain, Teaching Moment, Focus, Suggestion, Role, Support, Influence, Administrative	Encouragement/Praise, Personal Experience, Checking Up, Relate to Teachers, Students, Opinion, Paraphrasing, Focus on Standards
Curriculum Design Process	Influenced by Professional Development, Background Activity, Needing Support, Materials, Brainstorm, Unified Vision, Humor, Content Standards, Influence, Working in a Team	Organization, Pass the Buck, Visuals, Daily Goals, Outside Influence, Lesson Plans, Off Track, Problem Identification, Glossing Over Details, Someone Else Knows, Too Many Benchmarks, Lesson Sequencing
Teacher	Coach's Role, My Classroom, Idea Generator, Students, STEM, Past Experience, My Personal Context, Affirmation, Call for Action, Learner, Modifying, Last Year, Roles, Feelings	Uncertainty, Frustrated, Student Engagement, Question to Coach, Wild Idea, What Works for Me, Leadership Role, Role Reversal, Looking for Help
Curriculum Idea	Outside Influence, In Our Heads, Brainstorming, Decisions, Strategy, Spiraling, Fit with Standards, Being Critical	Contexts/Scenarios, Stealing an Idea, Explaining it to Another, Stuck, Explore More, In Our Heads, Defending, Whose Idea
STEM Curriculum Design	Standards (Science), Standards (Math), Engineering Design Challenge, Engineering Design Process, Engineering, Materials, Redesign, Communication, Teamwork, Creativity, Argumentation,	Data Measurement, Data Analysis, Design a Process, Science Location, Feasibility, Open-Ended, Apply Science and Math, Connection of Standards, Creativity, Prototypes, Constrains, Variables, Simplify

Initial to focus codes. Grounded theory analysis strategies require coded data move beyond an initial coding phase, to further levels of analysis. The second major phase of coding, takes this initial line-by-line or incident-by-incident coding and exposes it to focused coding. Charmaz (2006) states that, "Focused coding means using the most significant and or frequent earlier codes to sift through large amounts of data. Focused coding requires decisions about which initial codes make the most analytic sense to categorize your data incisively and completely" (p. 57). This level of coding is a creative and emergent process that is accomplished via a further examination of data. The process of moving from initial codes to focused codes for the team(s) was guided by the study's research questions.

In moving from initial codes to focused codes (and associated memos) the following analytical strategies were employed: (1) Initial codes that were related, connected, or similar (e.g. codes related to past experiences) were consolidated together. (2) As related initial codes were being read and analyzed, a concept map was created via a clustering strategy (Charmaz, 2006) to aid in visualization during analysis. Clustering allows a researcher to create a diagram in which a central idea or process is placed in the middle of a drawing, with related items being placed around the central concept of interest. (3) Initial codes were then placed into a consolidated, digital 'container' for identification of key extracts that aligned within specific categories of the previously mentioned figured. (4) Focused codes were then created using these 'containers' of related initial codes. (5) Identification of key extracts or interview responses that exemplified a specific focused code were then collated to further define and explain a set of related ideas, examples, and initial codes. (6) A free-write memo was then created synthesizing extracts from these focused codes to create a consolidated and cohesive narrative that weaved together the related but distinctive codes of each team of teachers and coaches. Charmaz (2006) writes that, "Memo-writing is the pivotal intermediate step between data collection and writing drafts of papers. … Memo-writing constitutes a crucial method in grounded theory because it prompts you to analyze your data and codes early in the research process" (p. 73).

Example: Initial to focus code. The following example will give further insight into the analytical process that was followed during the process of moving from initial to focused codes. Upon the completion of initial coding for an individual team, similar initial codes that were not previously coded together, but under the same top-level node were combined. For example, take the following three initial codes:

- **STEM Curriculum Design** - outside influence
- **STEM Curriculum Design** - frameworks/checklists
- **STEM Curriculum Design** - outside influence - word of advice

These three initial codes were combined under the code **STEM Curriculum Design** - *outside influence* because all 3 initial codes were related to an outside influence or orchestrations put into place that may have potentially influenced the team's thoughts about STEM curriculum design. Initial coding resulted in separate codes for each, but upon retrospectively looking at the excerpts coded in each exchange, it was deemed they were all related to the broader code, *outside influence*. An example of two codes that were originally not coded together can be found below:

- Mary: Sounds engaging! It seems like it would be, and it's true for everybody's…but, it may be easy to get super psyched up about the building and lose sight of the force and motion stuff.
- Nick: We should do that at some point (laugh). Or on the other hand, trying to say like well you know we went thru this checklist and there's several things on here which, we feel like are missing. You know that's okay.

The first extract was originally coded as **STEM Curriculum Design** - *outside influence* - *word of advice* and the second as **STEM Curriculum Design** - *frameworks/checklists*. Upon examining the extracts of each code, it was deemed suitable to combine the initial code **STEM Curriculum Design** - *frameworks/checklists* under **STEM Curriculum Design** - *outside influence* along with **STEM Curriculum Design** - *outside influence* - *word of advice* thus creating a group of consolidated focused codes with the following coding and sub-categorized codes.

- **STEM Curriculum Design** - *outside influence*
- **STEM Curriculum Design** - *outside influence* - *word of advice*
- **STEM Curriculum Design** - *frameworks/checklists*

Top-level nodes, and all subordinate initial codes were then cross-examined in search of commonalities. For example all initial codes were scanned and those that were related to coaching or a coach's role, were placed in a digital 'container'. An example of a group of initial codes that were placed in this container were: **Coach** - *idea generator*, **Coach** - *influence*, **Coach** - *role*, **Teacher**- *coach comes first*, **Team**- *role reversal*. These connected sets or digital containers were then analyzed during the creation of a concept map related to the top-level code: **Coach**. The concept map and set of coaching-related initial codes were then scanned for key extracts or exemplars that were indicative or insightful in relation to a specific aspect of coaching. These key extracts were central to the second layer of coding, focused coding, that exemplified a particular part of the coaching process. For example, in the following extract, Nick provided focus for his team by asking them the following:

- Nick: Let's…take a step back for a second. What exactly do we want them, forgetting about the design challenge right?

Extracts such as this further defined a key aspect of **Coaching**, *maintaining team focus*. This level of focused coding and key extract identification provided the basis for free-write memos that also took into account the previously mentioned concept map. These free-write memos partitioned out the key categories of a focused code while also providing narrative, descriptive, and inductive analysis of the data. Taken as a whole, these memos formed the written descriptions of each individual team during the curriculum design process. Free-write memos surrounding each focused codes were then organized into written descriptions that detailed the curriculum design process for each team. Additional data sources were included in this process as secondary data sources and were used to complete the written descriptions of each team. Secondary data sources included: pictures, curriculum design artifacts (e.g. large poster board creations), digital artifacts such as lesson plans or templates, or field notes. The inclusion of these secondary data sources allows for another data triangulation (Fielding & Fielding, 1986; Patton, 2002) in addition to intra-team and inter-team triangulation of coded conversations and interviews.

Theoretical Assertions, Conceptual Codes, and Evidentiary Warrant

The analysis process that generated initial/focused codes and uncovered exemplar extracts for each team resulted in the formation of three large (30-60 pages) documents that included narrative descriptions and example design conversation exchanges and interview responses. These three documents detailed the actions and exchanges of the curriculum design process for each team and allowed for the searching of patterns and theoretical assertions. As Erickson (1986) states, "The meaning of everyday life is contained in its particulars and to convey this to a reader the narrator must ground the more abstract analytic concepts of the study in concrete particulars — specific actions taken by specific people together" (p. 172). The search for theoretical assertions and "evidentiary warrant" (Erickson, 1986) was carried out by examining these three documents. This was accomplished via a two-fold analytical process: pattern analysis in search of "key linkages" (Erickson, 1986) amongst the data set and validity tests of major assertions against the data set. Testing the validity of an assertion against the database involves, "seeking disconfirming evidence as well as confirming evidence" (Erickson, 1986; p. 168) that either supports or refutes an assertion. For Erickson (1986) searching for, "disconfirming evidence is essential to the process of inquiry, as is the deliberate framing of assertions to be tested against the data corpus" (p. 147). Validity of major assertions, "rests with assertions that account for patterns found across both frequent and rare events" (Erickson, 1986; p.149).

The study's findings will be reported in Chapter IV using Erickson's (1986) guidelines for reporting qualitative research. Theoretical assertions will further be defined by describing conceptual categories. These conceptual categories or substantive codes, "relate to each other as hypotheses to be integrated into a theory" (Glaser, 1978; p. 72). As Charmaz (2006) states, conceptual categories, "explicate ideas, events, or processes in your data-and do so in telling words. A category may subsume common themes and patterns in several codes" (p. 91). In conducting an interpretive analysis, the researcher, "invites the reader's imaginative participation in related experiences through the *theoretical rendering* of the category. In this sense, the theoretical understanding of the category creates its significance" (Charmaz, 2006; p. 147). The significance of each category and associated theoretical assertion will be reported on by providing readers with *particular descriptions*, *general descriptions*, and *interpretive commentary* (Erickson, 1986). *Particular description* allows for theoretical assertions to remain grounded in the data from which it was taken by providing excerpts from the data, interview responses, and supporting data sources (e.g. curriculum design artifacts). *General descriptions* are used to, "persuade the reader that the event described was *typical,* that is, that one can generalize from this instance to other analogous instances" (Erickson, 1986; p. 150). This is done by providing evidence of the "generalizability of patterns" (Erickson, 1986) reported on in the study. Lastly, *interpretive commentary*:

> "This commentary appears as three types: interpretation that precedes and follows an instance of particular description in the text, theoretical discussion that· points to the more general significance of the patterns identified in the events that were reported, and an account of the changes that occurred in the author's point of view during the course of the inquiry" (Erickson, 1986; p. 152).

By describing the reporting strategy and analytical process that yielded those study's findings and major assertions, the researcher is aiming to provide transparency and openness to the study's major findings.

Theoretical Considerations

Symbolic interactionism and design conversations. To unravel the multiple meanings, symbols, interests, and influences that were exhibited and observed during the curriculum design process; this study was also informed by symbolic interactionism (Blumer, 1969). Blumer (1969) articulated three major premises of symbolic interactionism, all of which align with the purposes of this study:

> (1) Human beings act on the basis of meanings that things have for them.
>
> (2) The meanings of things arises out of the social interaction one has with one's fellows.
>
> (3) The meaning of things are handled in and modified through an interpretative process used by the person in dealing with the things he or she encounters. (as cited in Patton, 2002; p. 112)

Blumer's work is built upon that of Mead (1934), who theorized the relationship between individual mentality and the social processes that it must co-exist within. Mead (1934) states:

> (T)he human individual is possible because there is a social process in which it can function responsibly. The attitudes are parts of the social reaction; the cries would not maintain themselves as vocal gestures unless they did call out certain responses in the others; the attitude itself could only exist as such in this interplay of gestures. (p. 189)

To gain access to the social processes that occur during these interactions, Patton (2002) states that one must be in, “close contact and direct interaction with people, in open-minded, naturalistic inquiry and inductive analysis” (p. 112).

The purpose of identifying a theoretical framework allows the researcher’s interpretations, codes, sensitizing concepts, and analyses to be placed within the proper theoretical traditions. As Charmaz (2006) points out, “These concepts and codes locate your manuscript in relevant disciplines and discourses. Sensitizing concepts account for your starting point. Theoretical codes can help you explain how you conceptualize the arrangement of key ideas” (p. 169). The teachers, faculty, graduate student coaches, and administrative staff involved in this study engaged in creating semiotic meanings that were created via the language, behaviors, and actions they put into place during the curriculum design process. Revealing the theoretical framework of the study opens up readers to the types of questions that were asked and answered. As Merriam (2009) states, “the sense we make of the data we collect is equally influenced by the theoretical framework. That is, our analysis and interpretation – our study’s findings – will reflect the constructs, concepts, language, models, and theories that structured the study” (p. 70). For Mead (1934) and Blumer (1969), symbols and the interpretation of those symbols are vital to understanding human behavior, actions, and mentality.

Researcher’s Background, Role, and Subjectivity

My own background and role during data collection is also of interest given the interpretive nature of the study. At the time of data collection I had five years of experience as a secondary science teacher in urban, rural, and suburban school districts. I was a doctoral student in a Ph.D. track program (STEM Education) and had previously earned my Master's Degree (Science Education) from the same institution. I had three years of experience working with pre-service and in-service science teachers. Those experiences included working in an initial licensure program for science teachers, where I taught two graduate-level teaching courses. I also had various professional development experiences involving in-service science teachers focused around STEM education, technology integration, and teacher induction support. At the time of data collection, I had previous experience working as a curriculum development coach with two groups of teachers from the inaugural year of EngrTEAMS.

My role during EngrTEAMS was one of colleague, facilitator, and in general a participant observer. For Patton (2002), a participant observer, "employs multiple and overlapping data collection strategies: (while) being fully engaged in experiencing the setting" (p. 265). I also worked in close quarters with two groups of teachers during EngrTEAMS as a coach, albeit in a different content area (earth science) of the PD with teachers not directly involved in the study. I did have contact with participants during the PD, but those were limited in frequency and generally related to procedural items regarding audio recording equipment or the scheduling of interviews. I had previous experiences working with two participant teachers from year one of EngrTEAMS. I also had working relationships with each of the three coaches involved in the study.

My own subjectivity in data collection and analysis were highlighted above. This by no means will eliminate it from the study (Peshkin, 1988). In identifying this, I aim to denote how my own interpretations and past experiences were incorporated into the study. As Denzin and Lincoln (2008) claim, qualitative research is a, “situated activity that locates the observer in the world” (p. 4). This is a continuous struggle in qualitative research but also one that has given it its unique place in educational research. Patton (2002) accounts for this uniqueness by viewing grounded theory as, “fundamentally realist and objectivist in orientation, emphasizing disciplined and procedural ways of getting the researcher’s biases out of the way but adding healthy doses of creativity to the analytic process” (p. 128-129).

Limitations. The process of analyzing a large data set with the author being the primary point person for analysis yields for limitations and biases to present themselves in the analysis. However, a systematic and consistent method was used to store, filter, create, categorize, analyze, and theorize about data. The researcher’s previous experiences working with teachers during the design process, his experiences as a secondary science teacher, and previous relationships with coaches and teachers involved in the study also play a part in the analysis described here. Again, the methodology and theoretical framework of choice were implemented to account for these potential limitations with the aim of being transparent. In bringing in my own analytical lens to the process, I continually viewed this as a benefit, not a detriment to the process. My complete submergence in the data for an extended period of time, via audio, video, and written artifacts from the PD put me in a unique position to be able to answer the study’s research questions. One other potential limitation of note regards the nature of participant responses during individual interviews. Harris and Lambert (2003) note that the trustworthiness of participant responses can always be called into question in a qualitative inquiry of this nature. It is also necessary to state that theoretical sampling, a data sampling strategy used to further refine and potentially search for conceptual categories in constructed grounded theory (Charmaz, 2006) was not possible given the limited amount of time with participants and the vast amount of data collected.

Generalizability. The nature of this applied, qualitative study is not to generalize its findings across space and time. Rather, given the unique opportunity to collect and analyze a vast amount of data connected to the curriculum design process, the research purports to better situate future practitioners, academes, and other's understanding of the curriculum design process as carried out by teachers and coaches. As Erickson (1986) states:

> The search is not for *abstract universals* arrived at by statistical generalization from a sample to a population, but for *concrete universals,* arrived at by studying a specific case in great detail and then comparing it with other cases studied in equally great detail. (p. 130)

The analytical process of grounded theory differentiates itself from other qualitative research strategies via its procedures and purposes. Charmaz (2006) clarifies this understanding by claiming that:

> When born from reasoned reflections and principled convictions, a grounded theory that conceptualizes and conveys what is meaningful about a substantive area can make a valuable contribution. Add aesthetic merit and analytic impact, and then its influence may spread to larger audiences. (p. 183)

The data collection methods and analysis strategies implemented in this study aimed to further the research base involving teachers and various supports during the curriculum design process. Chapter IV will present the study's results in two sections, first by beginning with a narrative description of each unique design team and followed by the study's major theoretical assertion and conceptual categories.

Chapter IV: Team Case Narratives, Theoretical Assertion, and Conceptual Categories

Chapter IV presents the study's results in two sections. The first section consists of three narrative descriptions, or individual cases, of each unique team: *Team Engineering to the Rescue* [Team EttR], *Team Reckoning Force* [Team RF], and *Team Landmine Detonation* [Team LD]. Each of these individual cases will introduce readers to the members of each team and the accompanying experiences of each team as they worked to developed their STEM-integrated curriculum. The use of data in these team write-ups will be limited to phrases or commonly used terms used by each unique team. The choice to limit primary and secondary data sources in section one allows for comprehensive data sources and associated analysis to be presented in the second section of the chapter. Section two constructs the study's major findings by analyzing all three cases together via a creative and cohesive synthesis of the data.

Section I: Team Cases

Team Engineering to the Rescue (EttR)

Team participants. Team EttR was newly formed, with two of the three teachers having participated in year one of EngrTEAMS (Nathan and Matt). Table 4.1 contains contextual background and experience levels of each teacher in the group. The third member of the team, Sammy, was new to EngrTEAMS, but not to curriculum writing or the UbD framework that was put in place to guide the curriculum writing process. Given that all three members of the team were getting to know each other throughout the entire 12 days of the PD, the dynamics of the team differed slightly from the other two teams in this study. The team was coached by Nick, a former high school mathematics and physics teacher who also participated in year one of EngrTEAMS.

Table 4.1: Team engineering to the rescue background and demographic information.

Name	Years of Teaching Experience	Teaching Position	District Location	Gender	Previous Experience w/Coach
Matt	1-5 (3)	Elementary	Urban	M	EngrTEAMS & District
Nathan	11-15 (11)	Elementary	Suburban	M	EngrTEAMS
Sammy	6-10 (11)	Science Specialist	Urban	F	District

Team coach. Nick brought a few background experiences into the coaching process that differentiated him from the other two coaches in this study. Nick had worked extensively with pre-service mathematics teachers over the years and also lead the entire group of teachers on two separate occasions facilitating sessions involving meaningful applications of data measurement and data analysis in engineering contexts.

Nick's coaching style was predominantly revealed by the questions he asked during the PD. Nick's dual background in math and physics coupled with his background designing STEM-integrated learning experiences positioned him on solid ground to guide the team of teachers by asking them relevant and purposeful questions throughout the design process. He questioned the team frequently throughout the team's curriculum design conversations about their choices and actions. His questions were intended to keep the team on focus by requiring content-based reflection. He grounded many of his questions on the content standards they were working with during the unit's design. In addition to asking his team questions, he also provided the team with the following: (1) curriculum ideas, (2) opportunities for learning, and (3) praise. All three contributions were central to his role as a coach.

Nick's ability to engage with the team in brief and timely, content-related predicaments was evidenced throughout the data. Nick was able to share his content knowledge expertise with his teammates in an appropriate and respectful manner on multiple occasions. Nick was modest in regards to this aspect of his coaching ability, although he was aware that he played the role of expert at times.

The challenge. The team was aware of the challenging task they were attempting to overcome. A STEM-integrated unit needs to have students completing a design challenge, while they meaningfully and purposefully are applying their understandings of a scientific concept. The team continually juxtaposed how this application or transfer of knowledge gained from previous activities could allow students to 'get something out of the design challenge'. The team realized and actively discussed the fact that they needed to create an authentic learning experience for their own classrooms and that there were many problems they needed to address.

The team was interested in having a client that students could relate to. Therefore, they tried to add significance to the imaginary context of the unit by bringing in a local fireman to play the role of client at the start of the unit. The set up for the unit and final design challenge eventually morphed into the following: A local fire station is looking for a search and rescue vehicle that can maneuver over various terrains and overcome a few key challenges such as making a turn or going up a ramp, by applying forces. Students would need to demonstrate that their model designs for a rescue vehicle could be used during rescue missions in a variety of situations. The team was essentially trying to make a prototype that had a 'realistic analog' to a vehicle in the real world, such as a hovercraft or all-terrain vehicle that could be used by a search and rescue team. This was a challenging task for the team given the materials at their disposal and their desire to have students meaningfully apply their scientific understandings of force and motion to their designs. The team failed to successfully describe and write up this key aspect of their unit, though it was discussed extensively at all stages of the design cycle.

Curriculum idea considerations and influences. Team EttR actively considered three possible ideas for their unit. At Nick's suggestion, each teacher was asked to further develop one idea by paying attention to the three aspects of each idea: context, final design challenge, and standards that would be addressed. The three ideas that the team considered were as follows: (1) creating water bottle rockets, (2) designing an all-terrain rescue vehicle to be used by emergency organizations, and (3) designing a device that could safely transport water during a space mission. Formulating and developing these ideas resulted in the team discussing the pros and cons of each respective idea. This created a bit of tension as the team wrestled with each idea largely because each teacher took on some ownership of the idea he or she developed.

The idea that the team eventually decided upon (an all-terrain rescue vehicle) was intended to allow students to design a vehicle that would involve the testing and applying of various forces that would impact the vehicle's motion. The design and the choices students would need to make were also supposed to be influenced by varying the terrains that the vehicle would need to travel over (e.g. ice, water, sand). The decision to move forward with this idea was influenced by four things. Listed from order of most influential to least, the following list influenced the team's decision to move forward with the rescue vehicle idea: (1) content standards (science and math), (2) Nick's opinion, (3) past experiences writing curriculum, and (4) the materials to be used and the context for the engineering design challenge.

The team first and foremost took into account and continually revisited the content standards that the unit would be aligned to. Their conversations were constantly guided by the phrase, 'greater force equals greater change in motion'. From here, Nick's opinion of the unit idea was highly regarded. Nick's suggestions, tips, and ideas were strongly consideration by the team. The team continually juxtaposed their ideas about the unit with Nick's opinion in the backs of their minds. Nick's actions were considered as helpful because he had 'been here before'. Nick was aware of his influence on the team. He was also conflicted with how he felt about his influence. He felt tension between how much he should be actively collaborating with the team and how much he should simply be facilitating the group during the curriculum design process. This tension played out over the span of the curriculum design process and Nick ultimately engaged with the team more or less as an equal partner. The team was appreciative of Nick's role with the team and did not appear to recognize how influential he was on the team's curriculum choices and design. The last two influences, as will be discussed below, were given equal weight given the nature and frequency of conversations that revolved around each driver respectively.

Past experiences. Past experiences were given power and influence during the design process as the team continually mentioned that they did not want the unit to integrate too many content standards, something Matt and Nathan learned last year. The team used the word ‘spiraling’ with a negative connotation when it felt like the unit was becoming too big to handle. The team’s experiences previously designing curriculum were discussed in team conversations and mentioned in individual interviews. Both teachers who were involved with EngrTEAMS last year discussed how they were influenced this year. Sammy, who was new to EngrTEAMS, also indicated how her teammates’ comments and experiences last year had influenced her. The team was concerned about the unit becoming a ‘huge monster of a project’ or ‘over complicated’. They identified and discussed the ever-present connections that were designed in the science standards (e.g. the connection of gravity, friction, and motion), but determined that the inclusion of all three standards in one unit was something they could not successfully integrate into one unit. The unit needed to be short and concise with specific content standards in science and math.

Background activities were a resultant conversation piece as the team attempted to compartmentalize the content knowledge needed to work through the beginning lessons of the unit leading up to the final design challenge. Both Nathan and Matt experienced challenges last year designing their unit and they did not want that to be the case this year. Positive past experiences were also discussed, but were less influential on the team’s decisions and overall functioning. The materials that students would need to design their rescue vehicles was also frequently discussed and impacted the how the team functioned.

Materials challenge. The team continually discussed and worked with possible materials the students would be using to complete the build during the final design challenge. The challenge of trying to decide which materials students would be working with during the final design challenge warrants further discussion given the amount of time the team spent discussing this problem. The team quickly realized that they had a multitude of variables that the students would need to manipulate during the construction of their rescue vehicles. It was decided that students would be given a 'base vehicle' upon which they could design and build the mechanisms for propulsion, grip, and maneuvering. However, the options available were still plentiful and the ability of their students to take on such a challenge was questioned.

Specific conversations about the materials the students would have available to them during the design challenge were prominent. The team was aware of the amount of time they were spending with the materials as they frequently were searching online for possible solutions and checking with PD personnel on previously placed materials orders. The choice to use rescue vehicles was influenced by an activity the team had experienced during the physical science portion of the PD involving hovercrafts and compact discs. The team considered and consulted with PD facilitators about this activity, but given the nature of their unit idea, the materials to be used for the vehicle and propulsion method differed. The team considered propulsion methods that included propellers, balloons, and electric motors.

The team had many conversations as they tried to visualize what the final design challenge would look like for their students. This was challenging because they did not always have the materials they were considering in their hands. Some of the problems and associated questions they grappled with follow: What variables will students be manipulating? What will students be measuring? How different will each group's design be? What will the nature of the redesign be and what data will students use to guide their thinking during redesign? What will the constraints on the design be? How will students' design be assessed? These were just some of the problems the team identified and needed to address during the design process. Matt was very keen at identifying these problems, but struggled with how to address them once they were identified. Matt enjoyed the challenging nature of the work he was engaged in and was frustrated that he and the team were unable to address many of the problems revolving around the materials during their time together.

End result. In general, the team was genuinely engaged throughout curriculum design process. The inability of the team to come up with solutions to the problems they identified resulted in frustration and disappointment during the last two days of the PD. The team, primarily Nathan, drafted up some lessons that were more or less activities that he or a teammate had done before in their classrooms. Sammy worked diligently on filling in the UbD template, and unsuccessfully attempted to get the team to use the framework to design their unit with the end goal in mind, a central tenant of UbD. Matt was determined to figure out how to get the materials for the design challenge to work, though no personally satisfying answer was ever found. With no solid idea for how students would engage in the final design challenge, lesson plans that were drafted were limited and unconnected.

Team Reckoning Force (RF)

Team participants. *Team RF* consisted of four teachers, three of whom were science or STEM specialists, within the same suburban district, in different elementary schools. The fourth teacher was a fourth grade teacher from a gifted and talented elementary school located in an urban area. All four teachers previously participated in year one of EngrTEAMS. Table 4.2 contains further demographic and contextual information about each teacher. Their coach, Hank, had middle and secondary teaching experience, roughly three years, and a strong background in physics and STEM education. The team initially consisted of three members (Derek, Evan, and Michelle) until an invitation was put forward by Evan to include Jill in the group. There was one major distinction between the *STEM specialists* in the group and Jill, a classroom teacher, who worked with a different student population. Put bluntly, Jill was a 'classroom teacher' and not a 'STEM engineering-focused person'. This distinction was noticeable in team conversations. Evan and Michelle had paired together during year one of EngrTEAMS and Derek was paired with myself the previous year. Hank found himself amongst a group of teachers with varying personalities, teaching styles, and ways of conducting themselves in a team. His only previous relationship in the group was with Jill.

Table 4.2: Team reckoning force background and demographic information.

Name	Years of Teaching Experience	Teaching Position	District Location	Gender	Previous Experience w/Coach
Derek	1-5 (5)	Science Specialist	Suburban	M	EngrTEAMS
Michelle	>15 (24)	Science Specialist	Suburban	F	EngrTEAMS
Evan	>15 (26)	Science Specialist	Suburban	M	EngrTEAMS
Jill	>15 (20)	Elementary	Urban	F	EngrTEAMS & District

Team coach. Hank was a coach who understood that he was in a space where what he has been told should be happening, was not matching up ideally with what was actually happening. However, there were strategies that he successfully enacted during the design process to alleviate this tension. He was operating in a space between theory and practice, and recognized this. He felt that his connection to the curriculum his team was developing differed from the other members of the team and he therefore engaged in the design process and problem space differently than the teachers in his team. Hank was very on point with who he was as a coach, especially in real-time, design conversations. He abided primarily by three principles: (1) The standards provide a foundation upon which I can continually bring the team back to in conversation, (2) I am here as a facilitator, but when I feel the need to step into a different role, I will, and (3) I am not 'on the line', or responsible for the curriculum in the same manner as the teachers who have to teach the curriculum to their students, and this gives me less influence over the direction the planning process goes.

Hank attempted to relate to and partner with the teachers in his group during the design process. He related to his team by indicating that he was in on the struggle of accomplishing what they set out to do, and also hinted at how his previous experiences in the classroom were influencing his thinking during the design process. Given the unique makeup of the team, Hank also needed to relate to the feelings and actions of all members of the team. His concern was that Jill would dominate the team's design efforts and constrain the actions and behaviors of the other teachers.

Jill was held in high regard amongst the team. She recently completed her dissertation work and was very straightforward and upfront about what she wanted to accomplish with the team. There were times during the PD that Hank would ask Jill to take the lead with the team. The dynamics of the team shifted, depending on whether or not Jill was present, which occasionally she was not. The dynamics also shifted when Hank and Jill were present at the same time. This dynamic influenced the team and the design process for the group.

Curriculum idea. Team RF considered two ideas during the initial phase of the design process. One involved a passive transport system, which was conceptualized as utilizing force and motion standards to create a 'reverse roller coaster' system. This idea was never fully considered, especially after Jill made a connection with a local non-profit bike shop that was interested in partnering with the team, specifically her, given how close her school was to the bike shop. The team became interested in pursuing bikes after Hank facilitated the entire physical science group through a series of activities involving gearing, gear ratios, and bikes. The perceived ability of the team to have a real-world client resulted in many conversations about the nature of the work engineers' conduct, specifically as it relates to prototypes and the engineering design process. The team initially was lead to believe that the bike shop would be able to fabricate bikes that students designed. The premise being that a group of students would work on one aspect of the bike (e.g. frame, gears, breaks, etc.) and would complete a class schematic drawing that could then be created. The context of the design challenge was never concretely determined, and it initially revolved around having students design a bike, to get 'non-riders' riding.

Three of the four teachers were familiar with the Engineering is Elementary [EiE] curriculum that is focused on engineering more so than STEM. The opportunity to provide students with the chance to design a prototype that would actually be built was both novel and exciting for the team given this typically never happened while using the EiE curriculum. Unfortunately, after meeting with the manager of the bike shop, the team realized that the potential partnership was not going to fulfill what they had envisioned. The bike shop was more focused on advocating for youth to be able to repair their own bikes, than actually creating bikes in their shop. The team was then forced to rely back on designing a process that asked student to create a product (e.g. brochure, video, or website) that would help someone improve the efficiency of their bike riding ability (e.g. improved understanding of using bicycle gears).

Curriculum design challenges. The team struggled with two major aspects of the design process. The first was their inability to make decisions. They also struggled identifying specific content standards (e.g. simple machines, gears as related to input and output, angular velocity, balance and motion, etc.) to focus in on. The second challenge arose due to the complex nature and variety of connections the team uncovered related to the science of bikes. The team's inability to choose a set of standards to focus on was multifaceted. The first issue related to the previously mentioned complexity of bikes. Bikes, as the team discovered, are complex machines consisting of many simple machines that have many connections to content standards in all the STEM disciplines. Second, Hank's role as a facilitator for the team and not one of leader or decision maker hindered the team's ability to move forward with any specific set of standards. Ironically, one of the major supports that was added to the PD this year was largely resisted despite Hank's many attempts to convince the team to use the 'backwards design' process of UbD. Whether or not the process was unfamiliar or confusing to the team was uncertain. The team was torn between a variety of content standards and continuously contemplated which skills and content their students would need to engage in the unit. Ironically, the team's choice to not use the unwrapping process of UbD may have allowed them uncover the very skills and concepts they were interested in discovering. Hank was well aware of the team's need to utilize UbD, but never forced the team into actually using it.

Team RF continually hoped that decisions would be made by outside sources or 'ah ha' moments. The team was reluctant to move forward on deciding which direction to take the unit until they met with the bike shop owner and even created a document titled 'Questions for Jim' to bring up during the meeting. The team also prepared a 10-minute presentation to prepare for the meeting.

Overall, the team wavered back and forth on many aspects of the unit. No real decisions were ever made and no written curriculum was written because the team had no solid ground to write on. The team would talk about their potential ideas (e.g. an activity looking at balance and motion, identifying simple machines on a bike, measuring cadence, measuring input/output of wheel revolutions, designing a bike for someone with a disability, designing a manual to help someone ride a bike more efficiently) and created large daily lesson posters, but never moved beyond this step. The team's ideas sounded plausible and they were encouraged to move forward on their thinking via praise from others, but they never solidified their ideas enough as a team to move forward with the writing process. As a result, the team's time together resulted in many meaningful conversations and learning opportunities, but no written curriculum.

Hank was aware of the lack of written lesson plans and indicated his role was more about digitally providing comments and feedback on written lesson plans after they were drafted. His role was not to write the lesson plans. The team's lack of written lesson plans was brought up in conversation and in interviews, though not as an issue, but more along the lines of indicating that the process of writing lesson plans for a cohesive unit was challenging and that it would eventually happen.

Designing for my classroom. As the team continued to experience feelings of uncertainty while struggling with the design of the unit, the conversations began to sway in the direction of designing the unit for their own personal 'comfort zones'. This verbal massaging occurred as the reality hit that the PD was about to end and the team had no definitive understanding of what the 10-15 day unit was going to look like. Their conversations transitioned to what they could do in their classroom once they had to implement after the pilot during the upcoming year with their students.

There was no team-designed unit after the 12 days of PD. The ideas they had considered for the unit would presumably unfold via lesson plans that would be drafted on a day-to-day basis based on what they took away from their 12 days together. It was as if the group decided their contexts were so different and they had such varying teaching styles that they needed to just part and go their separate ways while having some loose connections to a curriculum that was 'co-developed'. Each team member had an idea in their mind of what the unit could potentially look like in their classroom. As a result, they struggled to work together as a team to come up with a unified vision of what the unit needed to look like when written up for an outside audience.

Team Landmine Detonation (LD)

Team participants. Team LD differed from the previous two teams. The team was small and consisted of two teachers who partnered the year before. Both Rita and Evelyn worked efficiently and quietly during the curriculum writing days of the PD. They worked in the same urban district for different schools and with a similar student population. Table 4.3 contains more information about each teacher.

Table 4.3: Team landmine detonation background and demographic information.

Name	Years of Teaching Experience	Teaching Position	District Location	Gender	Previous Experience w/Coach
Rita	1-5 (2)	Science Specialist	Urban	F	EngrTEAMS & District
Evelyn	6-10 (7)	Science Specialist	Urban	F	EngrTEAMS & District

The team's makeup allowed them to be 'on the same page' throughout the curriculum design process as they designed a unit for their own classroom contexts that would be taught at the beginning of the year to replace a unit involving scientific variables they currently taught. The team was quiet during the design process, which resulted in fewer curriculum design conversations. The team drafted an entire written curriculum, something no other team accomplished. The two teachers and their coach occasionally questioned why they were even being recorded. Their coach would also encourage them to talk about what they were doing because they were ‘being researched’.

Team coach. Abby came to the team having participated in year one of EngrTEAMS. She indicated during her individual interview that she had never coached teachers outside of her preferred content area, mathematics. This created a separation point for the team during the design process. Abby engaged in the curriculum design process differently than the other two teams, as she would refer to her teammates as being the ‘science experts’ and her as the motivator and ‘math person’. Abby brought in her experiences teaching high school math and her knowledge of STEM education. She has had previous experiences coaching math teachers.

It was not clear if Abby’s tendency to steer away from science content arose due to her lack of confidence in her own science content knowledge understanding, but given some of her comments related to certain science topics, it was clear she avoided conversations related to the science of the unit when possible. At times, Abby herself was a learner about various concepts (e.g. simple machines and force and motion), as the teachers she worked with would guide her through a particular concept. Both Rita and Evelyn were well aware that Abby had a strong preference for only discussing math and other non-science topics related to the unit (e.g. the unit’s context). They were also aware that science, and to a certain extent engineering, were not her area of expertise. Abby indicated that she would ‘pick up her ear’ when math was being discussed, though when asked if this had happened during her individual interview toward the end of the PD, she stated that it had not come up much yet.

It is also of note to mention the frequency that Abby brought up the fact that the team was being recorded and researched. She prompted the teachers to speak when quietly working, something that was not done by the other two coaches. This action took on a forced feel at times as she reminded the team that their actions needed to be studied to improve the quality of research related to teachers and curriculum design. Rita and Evelyn also spoke to me, via their tie-clip recorders, at times making humorous comments.

Curriculum design influences. The team ran very smoothly based on their previous experiences working together, and as a result was very decisive on deciding what needed to be included in their unit. There were aspects of the PD that were included in their discussions and considerations for the unit. Team LD was influenced by a resident engineer who suggested that they use a lever arm instead of building a more complex catapult. Catapults in engineering he stated had been ‘done to death’. With this piece of the design challenge determined, the team designed a unit that included a non-profit client that was hypothetically interested in a tool that could be used to safely disarm a buried landmine from a distance by launching an object that could precisely hit a target. The team’s coach influenced the context of the unit. Abby mentioned a story she had read about an elephant that was injured via a buried landmine. Students that would participate in the unit would need to design a launching arm, similar to a launching toy for a dog’s ball, which could be used to hit a specific target a set distance away.

Curriculum idea. The team's unit contained activities borrowed from other curricula (e.g. Foss Kits) that the teachers had used before. These activities were considered 'background activities'. Background activities were frequently talked about as allowing students the opportunity to be 'given' science knowledge to be used during a final design challenge. The main science content from the unit came from a portion of a benchmark related to simple machines, while excluding the second portion of the benchmark related to calculating input and output. An engineering design process was used in the unit that was based off the unit the team designed last year. There was a linear sequence of events that was to occur during their unit. The culminating engineering design challenge and associated build could be considered a science experiment involving first class levers, or lever arms. The design challenge asked students to manipulate the location of a fulcrum, vary the length of a lever arm, and use varying amounts of mass to optimize a set of variables while designing a lever arm. To justify the team's design to their client, the team was to write a memo explaining their design, while using the science concepts to 'argue' why their design was the choice to go with. This allowed the team to 'hit' argumentation and engineering/communication content standards.

The team identified that the unit was not 'math-heavy' and that during the unit, the math standards would support the engineering design, which would then support the science concepts. One could argue that the team constructed a science unit more so than an integrated science, math, and engineering unit; but that is not the purpose of this study. The additional opportunities that the team considered from outside sources included a more complex analysis of graphs, measuring force in addition to distance, and having students use a technology tool to display and analyze data. All three of these were briefly talked about but not considered to be in line with the qualitative math standard the team was considering. In the end, they decided to have students collect data that the teachers were comfortable facilitating. They also wanted students to collect data using a teacher-created table that could then be created into a graph for analysis for the class to interpret as a whole.

Curriculum design challenges. Team LD did not experience many challenges during the curriculum design process. In short, they identified what they wanted to do and resisted taking on anything that would require them to radically change how their classrooms typically operate. They were hesitant to move outside of their comfort zones despite suggestions by others to do so.

The team acknowledged that they were designing the unit in a manner similar to how they had the year before. When it came to utilizing the newly enacted UbB framework, it was just assumed that they did not need to use it as they had a notebook and outlining strategy that they had used before. Rita and Evelyn eventually completed the supplied templates for the unit, after the lesson writing process was nearly finished. The team got considerably more lesson plan writing done during the PD and even created an accompanying presentation that could be used with the unit. Backwards design was utilized, but in Evelyn’s notebook and a more familiar method.

Section II: Theoretical Assertion: Encouragement to Innovate and Design for Outside Audiences

Bringing together a team of elementary teachers and asking them to engage with a design problem like creating a STEM-integrated curricular unit needs to acknowledge how teacher tendencies and preferences will impact the process and product. If left unaddressed, the resultant product will be conventional, predictable, and akin to the learning experiences previously crafted and taught by the designer. When teachers are not acknowledged as designers, but rather teachers who are designing, they will first and foremost design curriculum with their own personal contexts and interests in mind. If the premise is that teachers have valuable insights, understandings, and knowledge of how best to work with their own and other students (which they do), then it is permissible to involve them in the design process. If however, teachers are merely supported to pursue their own ambitions during the design process without being acknowledged as designers and innovators, mishaps and frustrations will ensue. Teachers need support and encouragement to contend with complexity, address problems in strategic ways when they arise, and put their thoughts into action via the writing process to successfully design and write innovative curriculum for an outside audience. In short, treating teachers as designers and inspiring them to move outside of their comfort zones encompasses this study's major theoretical assertion: *Teachers need encouragement to innovate and design for outside audiences during the curriculum design process*. The conceptual categories and underlying themes that embody this assertion will follow in the second section of this chapter. Defining and grounding this major theoretical assertion and its underlying categories will be the data sources from which the categories and assertion arose. Figure 4.1 provides a visual overview of the study's main theoretical assertion.

Figure 4.1 represents each conceptual category for the study's larger theoretical assertion. The figure has two main components. The first piece is the "ball" that combines the many attributes, tendencies, and realities that teachers bring in and face when asked to be curriculum designers for a classroom other than their own. The second piece, the "hill", represents the challenge of getting teachers to move beyond their own classroom contexts and design for an outside audience. The upward slope of the hill is divided into two sections. The first section of the hill represents the process of *facilitating* teachers to design that only affords the ball to be moved half-way up the hill. The upper section of the hill differs from the first because it represents the process of *inspiring* designers who are also teachers. To successfully move the ball up and over the hill or challenge of asking teachers to design curriculum for an outside audience one must successfully push it along both sections: *facilitation* and *inspiration*.

Figure 4.1: Encouragement to innovate and design for outside audiences.

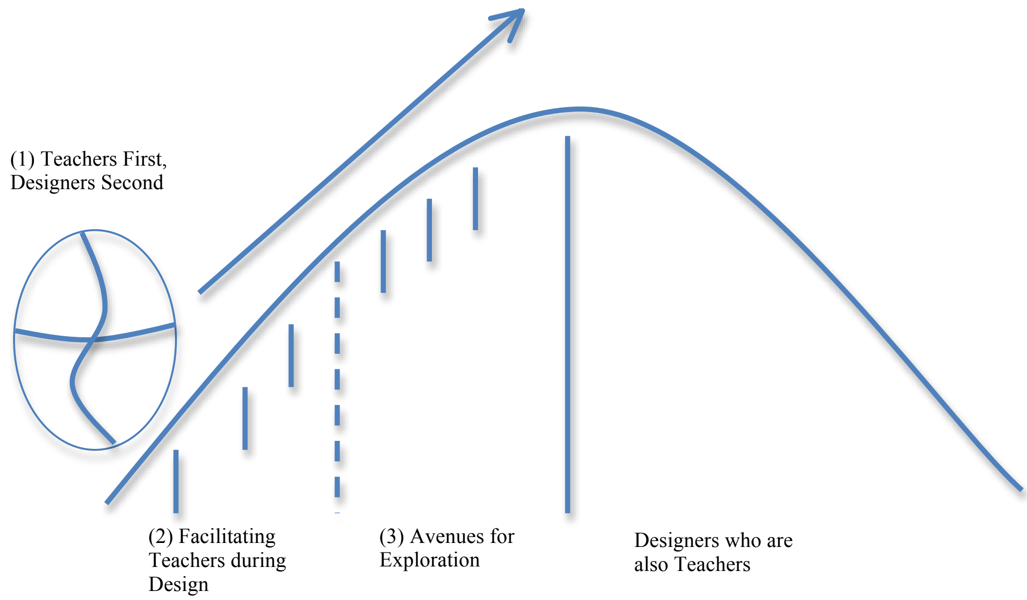


Figure 4.1 is accompanied by three major conceptual categories: (1) *Teachers First, Designers Second* (2) *Coaches and Professional Development: Facilitation*, and (3) *Avenues for Exploration* each of which are further described in the following section.

Conceptual Category 1 - Teachers First, Designers Second

Teachers come into the design process as teachers, first and foremost. As previously discussed, teachers do not think of themselves as designers. The findings of this study replicate this phenomenon while further describing the attitudes, actions, and behaviors that define a closely related category: *Teachers First, Designers Second*. I was aware of this line of research during the design phase of the study, but the extent to which it would come up during design conversations was not anticipated. To further expand and explore this category, four themes will be presented, described, and interpreted using primary and secondary data sources. Themes arose via the analytic process and consist of initial and focused codes that arose via analysis of the raw data. The four themes that make up the category *Teachers First, Designers Second,* are: *designing for my classroom*, *past teaching experiences*, *past experiences with curriculum and curriculum design*, and *background activities*. Table 4.4 provides an overview of the category and associated themes and sub-themes.

Table 4.4: Teachers first, designers second

Theme	Description	Sub-Themes
Design for My Classroom	The tendency of a teacher during curriculum design to primarily take into consideration his or her own classroom context.	my vision not yours, comfort zone, in my head, paint the picture, student motivation and excitement
Teachers Past Classroom Experiences	The influence that a teacher's past classroom experiences has on the curriculum design process.	teaching strategies, teacher identity, student abilities
Past Experiences with Curriculum and Curriculum Design	The inevitable impact that past curricula and curriculum design experiences will have on teachers during curriculum design.	professional development influences, professional development supports, Past experiences with curriculum
Background Activities	A collection of lessons, labs, or activities that are discussed as being essential to a STEM-integrated curriculum. Science content is typically "front-loaded" prior to a culminating engineering design challenge.	N/A

Theme 1: Design for my classroom.

My vision, not yours. Creating a uniform, team vision to strive towards is not easily accomplished. Teachers and coaches during the design process continually had conversations that indicated that they were envisioning different versions of the unit being played out in their classrooms, versus that of their teammates. The theme *My Vision*, *Not Yours* was therefore created.

The following exchange between Michelle and Jill of Team RF provides insight into how this played out during design conversations. Michelle, who was very soft-spoken in the group, has decided to bring her thoughts to the group's attention. She was concerned that her vision of the unit would be jeopardized if certain aspects were cut out or kept.

- Michelle: I think one of our concerns and mine as I've been listening is we have a lot invested in this. Plus we are trying to not only trying squeeze this out but add this in so it can work for us.

  Jill: Yes, and your needs are different than my needs.

  Michelle: Right.

  Derek: Right.

Here concerns are personalized and contextualized. She is aware of which activities of the bike unit she will be able to teach, and which will be out of reach or more difficult. She therefore indicates that she wants to have all possible lessons on the table for her to consider for her classroom. Jill acknowledges this and the fact that each member of the group does have different needs. Recall that Jill was the only member of the group who was not a STEM specialist. Derek also chimes in at the end, indicating is agreement with what has been said. This exchange and others similar in nature occurred often during design conversations. Teachers felt the need to distinguish how their needs and preferences differed from others in the group, and indicated that the unit be designed keeping in mind that each would have a slightly different vision of where the unit was going. There is no inherent problem with acknowledging that each individual teacher will implement the unit differently. The problem arises when you try to get different teachers on the same page and cohesively write a unit with one uniformly shared vision. Derek, in describing how his team worked together during the first year of EngrTEAMS exemplifies this difficulty.

- Derek: One of the things we struggled with was that we would each have our own vision and then we would talk and say “AH” let's diverge this lesson. So if we could do it (work together) a little bit more with the four of us talking about a lesson, then take a bunch of notes…

  Jill: And then split up?

  Derek: Yeah! Then do the writing.

Derek is trying to determine a strategy to alleviate some of the struggles his team experienced the previous year. Last year, each teacher would take a particular lesson and begin drafting a lesson, only to later discover that each member of the team had their ‘own vision’. Teachers are capable of realizing this, it’s just a matter of acknowledging the likelihood that teachers will have varying versions of how the unit will play out in their classrooms, and actively discussing each other’s similarities and differences (Remillard, 2005). Once this is aired out, the team can move forward and design a cohesive and connected unit. Team RF, again due to the makeup of the group (STEM specialists versus elementary teacher) really exemplified this theme. Two exchanges will follow, each one contains elements of the sub-theme *My Vision, Not Yours.*

The team more or less struggled with this creating a unified vision. Evan, in the first exchange indicates this with the phrase ‘there’s no judgment’ when discussing the variable contexts and preferences each teacher brought into the design space.

- Evan: I think we just have a different context, you know our contexts are a little different. So it's worth how we're going about this a little different so I think we can get it to go together and still make it work for both of us you know. There's no judgment like that at all, but I think the way; some of the needs we have for the way we need to do the work is a little different.

  Derek: Yep.

  Jill: But I think we're still hinging on the same thing which is….it's this (idea)…it's what, what is it…right?

  Evan: Right.

Jill follows Evan's declaration by targeting in on the issue that needs to be addressed, and the one the gives the category it's hypothetical punch. The unit will be 'hinging on the same thing'. Each teacher, having discussed the ideas and lessons that would be included in the unit has some connection to the overall unit's purpose: exposing kids to the science of bikes and having them design a product that can be used to improve someone else's bike riding ability. However, each teacher will accomplish this differently. With this underlying premise ever-present during design conversations, unified curriculum design is difficult. The reality of this hit's home, especially with Evan, during the final days of the PD. Jill, who was frustrated with the team's reluctance to have students create a different product at the end of the design challenge than what they were accustomed to (e.g. a poster), proposes that each individual teacher choose whatever they are comfortable doing, no matter how different that might be.

- Evan: Hopefully it won't be totally different…it'll be close.

Michelle: Okay.

Evan: Right ‘cause we kind of have a framework were kind of agreeing to, so we don't want to be like totally…

Michelle: No, we have a goal in mind and how we reach the goal is going to be different. How I do it compared to you is going to be different. How she does it compared to him and me is going to be different.

Derek: Uh huh.

Michelle: But hopefully, what we produce is going to be somewhat the same or the same idea.

Jill: Well it has to have those foundations, the benchmarks and it has to have the design and redesign stuff.

Evan is concerned about this. He emphasizes the word ‘totally’ when he realizes that Jill does indeed have her own vision for how the unit will be playing out in her classroom and this will differ from what he will be doing. Michelle, and eventually Jill, smooth over the predicament that Evan has uncovered by identifying that the manner by which each teacher will teach the unit ‘is going to be different’ and that as long as the team has a similar goal in mind, this is acceptable. Again, exchanges such as these were commonplace amongst the three teams. Teachers were typically involved in these exchanges, but occasionally coaches would reveal how this theme was created in all participants’ minds.

Nick (Team EttR), during his individual interview described the inescapabilty of not considering your own classroom context during the design process. When asked how his role would be different, or change if his role was reversed and he was a teacher in the team, the following transpired.

- Nick: Well no, when I'm a team member, it's something that I'm going to use in my classroom right. So it's like when we were talking about this thing, if I had a science classroom there's definitely ways that I would want to do it.

  Author: Yeah.

  Nick: So I would be like this is what I want to do cause this is what I want to do with my kids.

  Author: Okay.

  Nick: But they're not my kids you know, they're their kids so, they have to decide what they want to do with their kids on their own.

The initial interview question's intent was to uncover how, if at all, Nick participated differently in the design process given his role as a coach and not a teacher. And while he does indeed indicate that his participation in the design process would be different, it's quite remarkable that despite not being a classroom teacher for a few years, he still signals that he would have his own vision for the unit, because there would be certain parts of unit he'd want to 'do with my kids'.

The pull of having a classroom to take a newly designed unit into is immense. It pervades many curriculum conversations and individual teacher's mindsets, processes, and symbol systems. The choice to describe and explain this category first is a result of its prominence in the findings of this study. And while this has been identified in the research (e.g. Kerr, 1981) as being a benefit and consideration to take into account during the design process, its prevalence here further reconciles the need to be aware of its influence.

A search for disconfirming evidence, where a team would take up the task of actively discussing a unit's purpose in a search for creating curricular consistency (Huizinga, et al., 2014) yielded few examples. The below statement, by Sammy (Team EttR) is indicative of the extent to which teachers considered creating a unified vision of the unit, albeit during an instance of frustration and dismay.

- Sammy: We did not need to stay with this idea and feel like…Let's brainstorm some ones we like, let's be proactive 'cause I'm not attached to this at all. I think at this point I feel like I've had everything I have to say about it and I don't want to repeat myself. I'm not attached to it and let's think about something that would fit better. Are we still allowed to do that?

Sammy's statements here came after the team was being critical of the curriculum idea she was asked to further develop and report back to the team for further consideration. Here, she mistakes the team's constructive criticism for something else. She has very clearly just laid out to the team how the idea she developed could be played out in the classroom to the team and identified some problems that the team would need to address. The team's vested interest in picking apart the idea as a group indicated to me in this exchange that the team was attempting to create a unified vision, not an individual one. Instances such as this were emotional, raw, and memorable. Nick, the team's coach, during his interview a few days later recalled this exchange and noted how 'flustered' Sammy was when this occurred. The emotion, connection, and requisite conversation that needed to occur to uncover this emotional buy-in to the unit's vision reveals just how challenging it has to have meaningful conversations about a unit's purpose, something that has been advocated for in the literature (Remillard, 2005). The rare occurrences of conversations such as this demonstrate how a teacher's individual vision for a unit prevails in a teacher's mind during the design process; and if not unwound or actively discussed results in each teacher holding on to a personal vision for the unit the team is co-designing.

Coming up with an individual vision during the process of creating a team-designed unit does not just happen. There are behaviors and actions that present themselves during the design process that further defines how this solidary mindset can occur amongst a team of peers. Uncovering some of the behaviors, actions, and utterances that exemplify this counterintuitive phenomenon provides further insight into the larger category *Teachers First, Designers Second*.

Comfort zones. It was commonplace for teachers to indicate and discuss how an experience they had in the past could potentially be applied to a new or unfamiliar situation. When situations such as this occurred, teachers would take comfort in envisioning how their past experiences could help them when on unfamiliar ground. Involving teachers in the process of curriculum design and asking them to take on the task from scratch, results in teachers looking for chances to fall back into their comfort zones. Curriculum design has the potential to pull teachers out of their comfort zones and examine previously used planning and teaching strategies, with the potential benefit of improving their overall practice. Comfort zones are not necessarily harmful places to fall into, they just need to be explored, discussed, and vetted with the group to examine how they may potentially fit with a particular unit's outcomes and purpose.

During her interview, Sammy discusses how comfort zones are brought into the team design process, and how she has been processing the task designing a unit on her own, as a teacher, versus designing lessons in a team, for an outside audience.

- Sammy: You're used to working by yourself. It's almost that the…the adrenaline. Where you know, if you're lesson planning and you know…the kids. You're going to be teaching it sooner rather than later. Here, we're going more long term, which is really nice too. I like both experiences, but just when I plan with myself if I feel like it's time to brainstorm I do it! If I feel like it's time to go and get the materials or go shopping and look at stuff (I do). When I'm on my own, I go and research more on the Internet to see what has already been done to get inspiration, not to copy, but to get inspiration. I'm just so used to brainstorming on my own and planning out something on my own that (here) we're learning to work together. There's been no conflict, I'm just trying to figure out when I should be quiet, 'cause I talk more than the others (laugh).

Sammy is a veteran teacher and has battle-tested strategies for 'brainstorming' ideas for potential units, 'planning' lessons that would make up a unit, and 'inspiring' herself to create a learning environment that her and her students will thrive in. When she is asked to be a designer, she is now being asked to do something as a team with her peers. Her comfort zone is to take on the challenge individually. She may have strategies that would apply to this new endeavor, but as evidenced in her last statement, she is ‘trying to figure out when she should be quiet’. Teachers have a past designing curriculum that cannot be disregarded. Teachers will also have teaching experiences that they bring into the design process that influence how they design curriculum. These teaching experiences will also impact their vision of what they think is possible. Moving outside of their comfort zones, by designing a unit that asks them to do something that they are not accustomed to, needs to be done with care and encouragement.

Moving back to Team EttR, we have two different proclamations from Jill, during the same conversation about 11 minutes apart. These two exchanges were also initially coded as *my vision, not yours* in addition to *comfort zone*.

- Jill: Okay, so I wouldn't be surprised if you're overwhelmed by week three ‘cause it's overwhelming for me. I have, in my head, even though I haven't developed it yet, a pretty compact way to turn what they've (her students) learned into a video. If you'd be more comfortable just turning it (the final student product) into a brochure …or something that they've written, or like images with captions or whatever, that’s totally cool.

Here, a new wrinkle is added to the theme *my vision, not yours* and *comfort zone*. Jill, a veteran teacher with 20 plus years of teaching experience has quickly processed the potential avenues the unit the team has been discussing, and is now moving forward to visualizing the final student-created product; albeit for her classroom based on a model she is accustomed to. The phrase, ‘I have, in my head’ very nicely melds together the predicament teachers must be encouraged to overcome when they’re asked to be designers. Jill, as will be seen below, was not the only teacher to use the phrase, ‘in my head' or a close version of it during team design conversations. It happened frequently. When teachers are fail to conceptualize something like the final product of a unit, or write up more specifically what they are visualizing in their minds taking place, the idea gets stuck in their head and they keep it there to be developed for their own classroom. Teachers will search for alleyways or copouts to cope with the reality that what they are considering doing in their classroom will be different from what they have been working on as a team. Again, Jill, later on in the conversation reveals her thinking about what she will be doing.

- Jill: I know we are responsible for writing a curriculum, but think that…we could almost, if you wanted to go to your comfort zone in terms of what you create. Then we can kind of write up one of the ideas and then have the other under the teacher comments.

  Derek: Mm huh.

Jill had previously mentioned using a teacher comments section to account for the wide array of ideas the team was considering for each potential lesson. This, in her mind, would allow for each teacher to indicate how he or she would be teaching the lesson in his or her respective classroom and still allow them to be accountable for writing a curriculum. The extent to which any of the lessons would be written for an outside audience or with any cohesiveness could justly be questioned. The fact that Team RF produced no written lesson plans during their design time together is also indicative of how seriously the team considered Jill's 'teacher comment' strategy.

Evan, after the fact, was curious to know exactly what Jill had inferred was his 'comfort zone'. He was defensive here. He indicates this by declaring that in STEM, 'we do something tangible'. If Jill is considering 'making web pages', that's her prerogative.

- Evan: When you said go to your comfort level, what'd you think was my comfort level (slight laugh)? Making web pages is not my comfort level. Generally in STEM, we do something tangible thing that the kids build. It's hands on. They do tests with them, that's what we generally do.

Two veteran teachers are clashing here. Instead of taking up the possibility of building off of each other's expertise, they are left marking a line in the sand. Evan, the STEM specialist, and Jill, the classroom teacher, each have experiences and teaching strategies that when put to action in the classroom can help their students learn. This is the type of expertise we want involved in the design process and what allows for curriculum to more effectively bridge the gap between curriculum writers and teacher's on the ground floor. Unfortunately, the teachers in this team (and the others) considered themselves teachers first and designers second. They therefore were not able to reconcile their differences and take up the role of a designer and consider how teachers other than themselves would use the resources they were creating.

Completing the sequence of events that unfolded after the team decided to move forward; the following exchange between Derek and Evan demonstrates how each teacher would now move into their own comfort zones with Derek taking up the idea of having students create a brochure and Evan having students use a tri-fold to display their work.

- Derek: You can have it (students' work) displayed thru a brochure or a video.

  Evan: I got this cool trifold thing.

Michelle summarized the team's interactions and thought processes with the below declaration to the group.

- Michelle: It sounds like you can take up what you're comfortable with. It's not a time to criticize (each other), but (a time to do) what you think is important. She might think all this is important, I am not going to do it her way (laugh). You know what I mean?

The team at this point was nearing the end of their time together and individual plans of action needed to be taken. Michelle laughs here near the end of her statement in reference to the fact she will not be asking her students to create a web page, and also indicates to the team that being critical of each other's comfort zones is not ill-intended, it is just the reality that they were facing. She also indicates her individuality here, noting that 'I am not going to do it her way'. To further understand how teachers design for their own classroom, a more careful look at how each teacher locks up his or her ideas in their own head is merited.

In my head. Teachers are able to read each other very well when working in a team and as deciphered from their conversations can pick up on the fact that fellow members of the team may be holding on to a variety of ideas about a unit. They are also consider how each member of the team may be interpreting a given situation. The reason they are asked to be interpreters of their teammates' thoughts is a result of not openly and candidly discussing their thoughts and feelings about a unit's purpose and vision. As a evidenced below, this results in members of the team identifying that ideas are in their heads, or that their teammates may be holding on to varying thoughts.

Nathan, in the brief exchange that follows is discussing the challenge of attempting to conceptualize how a variety of materials could be used during the team's final design challenge.

- Nathan: I think that's based on not being able to physically touch anything. It's more of a mental concept right now than physical. (We aren't) able to see if it would work.

  Nick: Right.

  Sammy: Were visualizing a lot.

Even though this particular exchange was about materials, it is still worthy of discussion given the overarching theme. There is a lot of 'visualizing' that occurs during curriculum design. Problems must be dissected, plausible solutions must be explored, and teams must accomplish this together largely via conversation, requiring a lot of 'mental' processing as Nathan stated. This is a necessity of curriculum design and therefore can result in individual teachers harnessing and holding onto ideas in their minds that if not properly addressed keeps them in the mindset of teacher first, designer second.
Evan does this again below in the following statement to the team.

- Evan: One way I've been thinking about this, is that each group of three would be designing their own bike. Your jigsaw idea kind of gives me the thought that maybe we do it different. We say all student teams are going to design around one bike.

Evan is processing his thoughts here and also revealing how his thought process is evolving. The team, particularly Evan, was very perplexed with how he was going to be able to handle 10 groups of three students each designing their own bike during the design challenge. During his individual interview, Evan indicated how much of a breakthrough it was for the team to discover the 'jigsaw idea' and also clued me into his own struggles with the direction the unit was initially heading.

- Evan: I keep poking, trying to make sure that were not up here (moving his hands back and forth next to his head). We need to…it can be up here and can…You know when you're talking about standards and you're talking about a rationale for why you're doing (it). Ultimately it has to come down to the tabletop with the three kids around it.

Evan was often seen as the person who asked these types of questions, he 'poked'. He was the practitioner of the group. He was initially concerned about classroom management during the design challenge where it was originally thought that 10 different bikes would be assembled during the final design challenge. He was able to alleviate these concerns once the 'jigsaw' idea was discovered, but initially this concern was looming in his mind. Evan was eventually able to come out and describe how this new idea helped him in conceptualizing the unit, but his consistent questions 'poking' at each and every potential idea was personally conflicting for him. He was not sure if he was supposed to be doing this. This came out the next day, as the team was in conversation.

- Evan: This (idea) is excellent. And for this…I hope you're not hearing me, that I'm being critical.

Derek: No!

Michelle: No, it's totally…it's totally designed to…

Hank: Critical is good.

A few more examples, to further demonstrate how frequent the teachers would indicate how ideas were ‘in their heads’ or how they were picking up on each other interpreting situations and ideas differently follows. First, Hank, during his individual interview. Hank described how the team worked during the design process. Team RF, as lead by Jill, used large sheets of poster paper during their conversations.These posters were a venue to get one member’s ideas out of her head.

- Jill: I'm relieved to get all this up. I'm sorry if it's overwhelming, but like it was in my head and I just wanted to get it out. What we do with it, I’m less attached to, but just so it’s out.

This strategy, as described by Hank, further explained how individual teachers keep their thoughts in their minds, when not overtly asked to speak to each other as designers.

- Hank: Well, they've all been kind of sitting in the middle (laugh). Well not quite, Jill's been up drawing things which is fine…But sitting in the middle and as they're talking amongst themselves, they're pointing at the poster here, or saying “ah” the concepts that we wrote over here, that'd be a great fit for day four. So there's a lot pointing.

  Author: Spatial and pointing.

Hank: Yeah, and that has been helpful for some people who maybe aren't as conversational. They're sitting they're looking and they're listening. They're nodding their head. Okay, I get it now.

The use of large visuals that display daily objectives, lesson summaries, and activities for individual lessons is a reasonable strategy for allowing teachers to think about and process how each potential day of the unit can go. However, these posters were created by Jill, and used to dictate what she wanted to transpire of the 10-day unit. Even though she indicated that she was not 'attached to' what was being displayed, her dominant role in the group did not allow for other's to interject from where she wanted to steer the group.

Two more examples that illustrate how teachers picked up on each other's varying processing methods follow. The first from Derek indicating that each member of the team may be perceiving a proposed unit plan of action differently provides the following.

- Derek: At this point, I think we're coming up with like…Okay, in our minds how are we picturing…how we would use this right now? Do we think we could?

Derek is speaking for the other members of the team whom he works with (Michelle and Evan). Jill has proposed a plan of action for each individual day, and Derek, who could be considered the vocal leader for the other two members of the group, brings up the fact that even though Jill has an idea in her mind, it's worth taking a step back and making sure that all members of the team have the same idea moving forward. This was taken up by Evan, who later reiterated that even though a suggested pathway had been displayed, he needed to get a 'better idea' of what exactly what this meant.

- Evan: We seem to have a model in our minds that it's going to be 10 or 12 days. One of the things I need to get is a better idea of what's happening each day

  Jill: Yeah.

  Derek: Yeah.

Evan acknowledges what Derek has brought to the team's attention by indicating that each person may have a 'model in his or her minds'. He wants to move forward by better describing what exactly this model is going to look like for the team. He again noted this later in the day via his daily reflection.

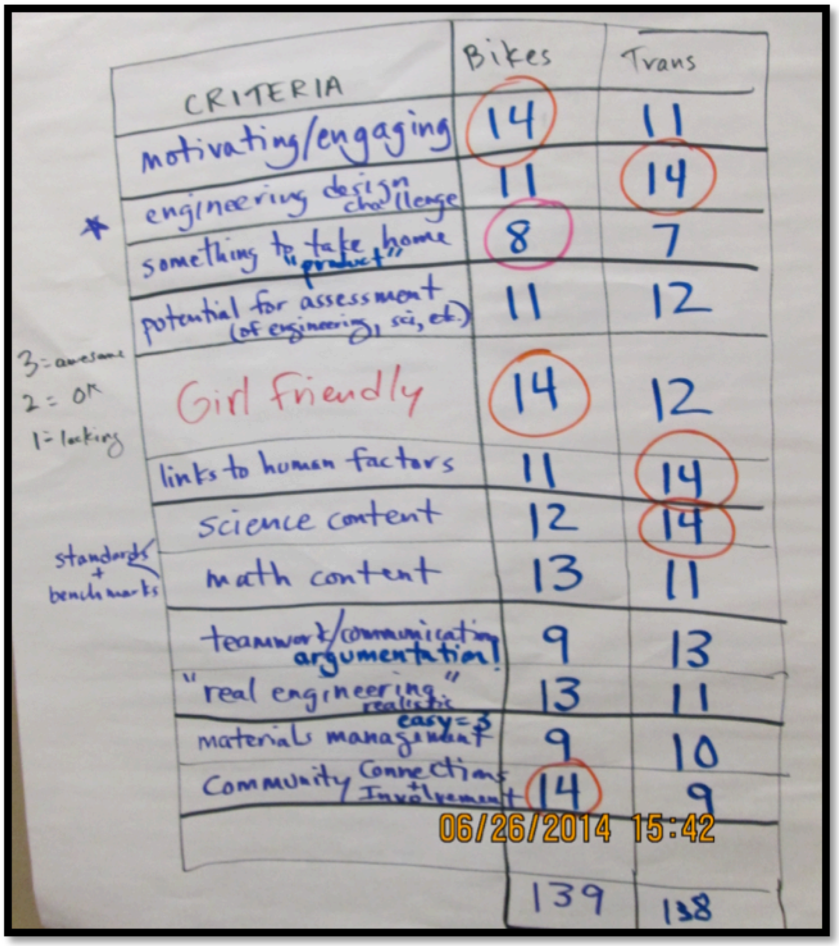
- Daily Teacher Reflection – Evan (Day 6): If we work hard to talk more specifically and clearly about where we want to go with our unit. A goal was to get our four minds thinking in the same direction.

One last example involving Jill that took place after the team developed a scoring system for two plausible unit ideas the team was considering. The team wanted to come up with a democratic way of deciding which idea to move forward with. Their solution was to give each teammate the ability provide a numerical score, on a scale of one to three, for one of twelve categories (see Figure 4.2). However, as Jill describes below, just providing a number fails to do enough to get each other's individual
'biases' out in the open.

- Jill: We seem to have biases, but maybe, in how we're perceiving the category.

Here, the team was asked to provide a numerical score for one of twelve categories (see Figure 4.2).

Figure 4.2: Curriculum design artifact, team-generated scorecard for curriculum ideas.



The summation of each category for each respective idea would result in the team moving forward with one of the two ideas. Jill's declaration to the team that even though the team attempted to democratically 'vote' on how well each idea ('bikes' or 'trans') aligned with each category (i.e. science content), there still were issues regarding how each member of the team was 'perceiving' each category. This declaration of misperception again highlights the likelihood that teachers will individually hold onto their ideas and perceptions during the design process.

One final exemplar from this theme comes from Derek's individual interview. Derek was asked about the importance of being able to talk about his teammates' ideas, a strategy for getting teammate ideas out of their head and into the open for others to consider.

- Derek: I think that sometimes when we hear a good idea and we're kind of…we kind of skim over it. We keep going along with other ideas, when we need to slow down and really think thru it. If we take three extra minutes on this one thought that we had, we might really turn it into something pretty awesome. Whereas if we just keep throwing down single ideas, I think it takes longer for you to really get a quality thought on something, especially as a team.

It takes time to process each other's thoughts. Derek indicates that as the team has been throwing out a variety of ideas for the team to consider that it may be happening too quickly. Teachers need to need time to process and consider what is being said. Ideas need to be explored, discussed, and actively consider. Ideas that are briefly mentioned and passed aside are less likely to be considered. Without further exploring an idea and taking the time as a team to 'slow down', members of the team may hold on to what they have previously done in their classrooms. They therefore will never really move towards anything new or innovative because they were not given the opportunity to process the ideas that are in their heads or their teammates.

The lack of exemplar exchanges between Team LD in the category *Teachers First, Designers Second* is of note here. It could be considered disconfirming evidence given that Rita, Evelyn, and their coach did not have as many conversations that exemplified the previously described themes (e.g. *comfort zones* and *in my head*). However, I would argue that the previously mentioned relationship between Rita and

Evelyn, the similar student populations that they each work with, and the unified goal to use the unit they designed during EngrTEAMS to replace a pre-existing unit they had each taught before allowed them to seamlessly navigate through the design process without being tripped up by the difficult conversations typical of this category. The team was on the same page throughout the PD, talked minimally, and was even prodded to talk more by their coach. They also exceeded the other two teams in regards to drafting lesson plans. The manner in which the team functioned together varied from the other two teams, which allows for variation to be exemplified in this category. Evelyn during her interview identifies this point perfectly.

- Evelyn: So that's kind of where we are. We're stuck on the redesign. How do we extend it and the justification from students afterwards? So it's there, it's in our heads. It's going to have to be some type of memo that they would send off to M.A.G. (the client).

Evelyn talks with confidence about her own thinking and her partner's. The problem and potential solution related to the redesign is not in her head, it's in *their* head. They both know it's there, they've conceptualized the problem and potential solution, they just have not precisely nailed it down yet. Statements such as these were only found from Team LD. Again, most of this was attributed to the unique relationship and circumstances that exist between Rita and Evelyn. The very fact that the team was able to draft an entire first version of their unit speaks a bit to how vitally important it is for teachers to conceptualize their ideas with their team. Without the hurdles associated with the previously discussed themes, teachers can continue moving forward as teachers designing lessons for their own classroom. This was the route taken by Rita and Evelyn.

Paint the picture. Having a unified vision, or internal curriculum consistency, amongst a team of teachers during the design process is important and sought after. The light at the end of the tunnel needs to be bright, illuminating, and clear. This final sub-theme ties the previous two sub-themes together by providing some exemplars from Team RF who struggled throughout the design process with getting everyone's thoughts on the same page. Below, Derek is catching Hank up on what the team had produced the previous day during Hank's absence.

> Derek: We've got our…well that was, all our thoughts on one page in big bubbles. That is kind of where we're at right now.

This exchange was fairly early on in the design process, just after the team had decided to move forward with the science of bikes idea. The team had been contemplating many different areas that could potentially be developed for the unit and they chose to put their ideas down on large sheets of poster paper in 'big bubbles'. The team was hoping to paint the picture, though in very broad strokes. Everything that had been talked about needed to move from the spoken word to something tangible, something visual. The team had been using short phrases (e.g. "the gear activity") to describe different aspects of the unit prior to this event.

A similar exchange below has the team discussing the context that the unit and engineering design challenge will be embedded in. Recall that the team had a potential real-world client (a non-profit bike shop) that would presumably be able to partner with the team; however, the specific details of what exactly the bike shop would desire during the design challenge was unknown. The team identified that once the context of the unit is determined, they can move forward.

- Evan: I think one piece that I struggle with is that we still don't have a context.

  Jill: Yeah.

  Evan: I think if we come up with an idea…

  Derek: Other stuff starts to flow once there's a context.

What exactly would their specific context be? The team was unsure of at this point. Would the bike shop be interested in creating more storage and carrying capacity on a bike? Would they be interested in having students design a blueprint of a bike that would serve a unique population of riders (e.g. veterans or the elderly)? These were still undecided. The team had no clear vision of a very important aspect of the unit, its context. The team hoped that the bike shop would be able to answer some of these questions and actually 'fabricate' a bike based off of their students' designs, once they determined the exact context.

- Evan: One of our desires was if we (his students) came up with a… a…design, that they (the bike shop) could fabricate up, that they could actually make it (the bike). Right? Isn't that what we were thinking?

The team has identified the value in fully being able to conceptualize how a unit would play out. Having these larger pieces put together and fully known to all members of the group provides building blocks upon which further problems can be identified and solved. Not having these pieces in place, as in the case of Team RF, puts a design team at a major disadvantage during the design process.

In retrospect, after better learning who Evan was a result of hearing his conversations with colleagues and analyzing his individual interview, it's clear that he was a very insightful person and very vested in working with his students and providing them with quality learning experiences. His struggles during the PD, and the team's lack of clearly identified purposes and contexts for the unit come out in one particular interview response. When asked about what advice he'd give to a veteran teacher, like himself, just beginning the design process, he provided the following.

- Evan: Yeah, be brave and just…it's okay to struggle and not have the whole picture right away. Sometimes it will take us… It's a big; it's a big complex thing that you're attempting to do.

Evan was somewhat taken back when asked this question. His response was not so much emotional, as much as it was appreciative. After listening to his response repeatedly, it was evident that he was awestruck with the complexity of designing a STEM-integrated unit for an elementary classroom with a team of your peers. It's a challenge. You will 'struggle'. You will not always have the 'whole picture' right away, but be 'brave' and you can get there. Below, one last excerpt from Evan that indicated the importance of painting a picture for a unit that is consistent amongst the group.

- Evan: I'm always trying to think about what's this gonna look like in my classroom with 10 groups of three (students). How am I going to practically do that? What are the kids gonna do? What am I going to revive in them? So that's' kind of where I'm coming from. When I look at this, that's what I'm thinking about. How? How do I do that? How do I do that with my kids?

Evan's students, first and foremost are always on his mind. He has been in the classroom for over two decades, why would his thoughts not come back to and be centered on his students. No matter what the team is designing, Evan held his students and his responsibilities as a teacher in his mind. The challenge is to help Evan, and every teacher, balance the need to think as a teacher with their responsibilities as a designer.

Student motivation and excitement. The last sub-theme of interest nested under *Design for My Classroom* involves the declaration that students would have fun, be motivated, or excited to be a part of the STEM-integrated unit that the team was designing. Data from this subset round out the category and further identifies the tendency of teachers to design for their own classroom because of the 'fun factor' associated with teaching STEM in their classrooms. Teachers wanted their students to be learning, first and foremost; but if their students could have fun during the process, even better. A few examples, some from individual interviews and others from design conversations, illustrate the need for teachers to design motivating and exciting unit; because ultimately they will get to be the ones who get to teach the unit first. Matt, in the below interview response below, talked about the importance of having a 'fun context' for students to engage in during the unit.

- Matt: It provides a fun context for that, so it's like an engaging context for students to see that forces change motion: starts, stops, and turns. It's going to get them really engaged and they have to think about forces in different ways like with the friction slowing stuff down or forces that push or forces that would turn it. I mean they have to think about the force in different ways; to get lots of hands-on experience with forces. Measuring the effects of forces, things like that.

From Matt's response, it is also evident to see that he is connecting science content and student engagement together, while he talks about the engineering context. This is important to him, because it is something fun and different that he can bring back to his students, while still maintaining the connection to the standards that he is required to have.

A few quick excerpts below that echo Matt's response above further provide evidence of how important having a motivating and engaging context for the unit to take place in.

- Derek: Depending on the time of year, I could see some kids bringing in their own bike and being motivated about that; at least for the background and exploration piece.
- Michelle: I think that would be cool…there's a lot of kids who come from pretty dysfunctional families and I think it would be cool if they bring in their bike. I see the kids on their bikes all the time.
- Jill: We have spots to add activities cause it's really important to us that the kids do hands on stuff

Each of these statements in one shape or form mention student motivation or teacher excitement about a particular aspect of the unit the team is designing. These types of statements indicated the importance of having a unit that was enjoyable to teach and for students to participate in. This is important to this category and theme because it provides further evidence that teachers strongly consider themselves teachers first and foremost, and that their design decisions will circulate back to the realities of their classrooms.

Researcher transition. To illustrate how my thinking transitioned during the analysis process while uncovering and developing the theme *Design for my Classroom*, which eventually supported the broader conceptual category *Teachers First, Designers Second* a look at an early memo written about the theme will help. My early thinking about this category was not *Teachers First, Designers Second* it was *Teachers, not Designers*. I was confused by the conversations taking place and the lack of definitive action being took up. I was waiting for coaches to interject and help their teams during key decision points or dilemmas. I had an incomplete understanding of the category. I questioned the ability of teachers to be designers. Teachers were making choices based solely on their own classroom experiences, contexts, and needs. They could not move beyond this and no one was asking them to do so. I wanted to hear definitive conversations about what type of learning experiences the team could design for someone else's classroom when all I heard were more conversations about each individual teacher's concerns and thought processes. For example, when I was first contemplating creating the initial code *Teachers, not Designers*, I repeatedly examined the following exchange.

- Matt: How many days do we want this unit to be?

  Sammy: So I…my kids will be on a rotation of three weeks, so three weeks will be perfect for me. Yesterday we were talking with Nick and Nathan, and I'm thinking maybe I will go longer than you guys. I don't want to do that and bias you guys if you don't want to go longer than three weeks. But…Nick said it's gonna run three weeks, like plan for two weeks and it's gonna go over.

Matt: Well and if we need to, we can always modify it for our classrooms that we each teach in

Sammy: Yep. That's what I was thinking.

Matt: So I mean it's totally fine if you have a little bit different plan than everyone.

This conversation resonated with me for a while as I attempted to understand each teacher's thinking and proposed pathway for action. Were they capable of moving beyond their own classrooms, or was this always intended to be a curriculum project that would not move beyond their own classrooms? These were questions that I grappled with as I continued to hear, transcribe, and code similar exchanges. Below, is the initial memo I wrote after analyzing this exchange.

- Researcher Memo (10/27/2014): It's quite telling in this passage that Matt is ill concerned with other classroom contexts outside his own with statements such as, 'well and if we need to, we can always modify to for our classrooms that we each teach in'. Here he is indicating that the unit will be designed for his classroom, and that any applications of it outside his classroom are reliant on other teachers that are outside of his control and concern. Had he been thinking of designing the unit for other classrooms, there are plenty of avenues this conversation could have gone, including one of flexibility in regards to curriculum design, that could allow for individual teachers to adapt and augment the curriculum as needed for their own personal contexts.

It is not necessary to be a teacher to understand the category, though it may help. As I continued to listen to and analyze each team's conversations it began to emerge that teachers were designers, it is just that they came into the design space as teachers first. The appeal of being able to take a gift, like a new curriculum, back to your students and your classroom is immense. Combine this with a teacher's past classroom experiences and you have a potential conundrum: How do you get teachers to think as designers first, while still utilizing their past experiences in the classroom? Having the time and resources to design new learning experiences for your classroom is a luxury. When teachers do get the chance to design curriculum, even if it is supposed to be for an outside audience; they will make the attempt first as teachers, then as designers.

Theme 2: Teachers' past classroom experiences. The next theme that makes up the conceptual category *Teachers First, Designers Second*, dives more deeply into curriculum design conversations where teachers would discuss their experiences in the classroom. Experiences that will be discussed here include past experiences involving teaching strategies, indications of teacher identity as determined from past classroom experience, and lastly teacher perceptions of students and student capability based upon previous experiences in the classroom. Bringing in this strand of exchanges allows one to get closer to the design space and the reality of how ubiquitous past classroom experiences are for teachers.

Teaching strategies. As previously mentioned, teachers have valuable insights and strategies that can be written into a curriculum. Having first-hand knowledge of potential lesson ideas that have been successfully implemented or experimented with, brings in the potential for designing a unit that is more practical for a classroom teacher to implement. Sometimes however, a particular idea or teaching strategy may not apply to a potential unit's purpose, or be particularly effective or appropriate. It may just be familiar and comfortable. Being able to determine when one's past teaching experiences can aid in the curriculum design process is not easily done, especially when you come to the design space thinking as a teacher first and a designer second. Sammy for example, attempted to steer her team's thinking about a rocket launching mechanism. She indicated that she prefers a design that is more open-ended.

- <u>Sammy</u>: Yeah, if we go to that as the launching method for the rockets, instead of another method it would make it pretty teacher-dependent on the testing. I try…not that it wouldn't work. I try to avoid teacher-dependent. I try to avoid having the teacher there for a test, especially for a long-term challenge.

Sammy is taking into account her years of teaching experience working with students during labs and 'tests'. It is cumbersome and near impossible to have to logistically manage a classroom full of students attempting to perform the same test when the teacher needs to be involved in order for each group to do the task. This pragmatically makes sense, and is a worthy consideration. However, she picks up that her teammates may have past experiences using a more guided approach, and notes this by stating 'not that it wouldn't work'. Here, Sammy's past experiences could have aided in the design process had her and the other members of the team considered themselves designers first and not teachers. It is not that the idea was rejected; it is the fact that she wanted to use her experiences to design the curriculum, and could not forcefully suggest a strategy she had successfully used before.

Another example, with Rita and Evelyn, occurred as they were discussing data collection and measurement strategies for their launching arm land mine tool.

- Rita: You can just draw that on the board as an example. I've done that before with students. This is going this way and this is going this way, subtract the two and you can always have this minus this and have negative numbers. That way, it moves one way or the other.

  Evelyn: True.

  Rita: It could be a simple formula they could see and use pictures and arrows.

  Evelyn: So the first part might be identifying the forces.

This particular exchange, initiated by a previous teaching strategy Rita had used in the classroom, allowed the team to overcome a problem they were attempting to solve. The two are essentially discussing having students construct a number line to aid them during the data measurement stage of the design challenge. One more example from Rita follows. This exchange varies from the previous in that we get a bit more contextual background into where she picked up the teaching strategy the team is discussing.

- Rita: You could do it on pendulums, but not actually do it. It’s because it's easy to see it, but I think the fulcrum is easy enough where they could find ways to change it. I know when I did the variable sort; the only problem they (students) have is like figuring out that something you can change is like lifting it up to change the angle. So…you have to guide them to that cause the flipper design is something flat with a stick with tape.

The ‘variable sort’ activity is one taken from a science kit she and Evelyn have both used before. She is discussing how to get students to realize that changing the location of a fulcrum on a catapult, can impact the distance an object will travel, by using a pendulum. Here, Rita is thinking they can apply the lesson to the team’s catapult idea. She notes from her experience using the ‘flipper design’ (again from the science kit) that students need some guidance assimilating their understanding from the pendulum activity to the new redesign. This information is valuable, and is something that the team considered when designing their curriculum. It also demonstrates the value of involving teachers in the design of curriculum materials because it shows how a previously designed lesson (the pendulum) gets modified once teachers take it into their classroom.

The example that follows displays how seamlessly teachers will attempt to insert a previously taught lesson into a new curricular unit. Matt, whose team was interested in exploring force and motion via a design challenge involving the construction of a rescue vehicle, brings up the following lesson idea he’s used before.

- Matt: One lesson I've done before is where you like drag something, like a tray of weights or mass over different surfaces; like sandpaper, a table, or carpet. You use the spring scale to measure the amount of friction.

This previously taught lesson involving force fit in with the unit’s content standards; but does not necessarily fit in with the overall flow of the unit. For instance, why would an engineer need to assemble a sliding cart with varying amounts of mass in it to better understand how friction works, given that the vehicle a team would be assembling would be a hovercraft or vehicle with wheels. The concept is there, but the connection is loose at best. There may have been other activities that the team could have designed that would have more cohesively connected to the unit's overall design. Figure 4.3 shows a snapshot of the lesson plan that the team eventually drafted based off of this idea brought to the team's attention by Matt.

Figure 4.3: Team lesson plan that was drafted based off of a teacher previously implementing it in his classroom.

Lesson #2: (Name)

Lesson Summary:
Students will be introduced to Force and Motion / Push and Pull concepts. Students will explore Friction using a tray, textbooks and Spring Scale to measure the force it takes to move the tray with different weights. Students will experiment with Friction and measure their results. Students will record their data in their Science Notebooks. Students will repeat the experiment 3 times with different amounts of weight. Repeat this investigation on a different surface. Record on a table and then display the results on a Line Graph.

Lesson Objectives:
Students will know what Force and Motion are by the end of class. Students will know what types of Force and Motion / Push and Pulls they have experienced in life.

Time Required:
50 minutes

Materials:
Teacher Computer
TV/Smartboard
Student Science Notebook
Spring Scales
Text Books
Tray
Science of Disney
Imagineering-Friction
Digital Scale
Force ID Worksheet

This last statement from Evan will allow readers to view how past teaching experiences can have a potential negative impact on a teacher's thinking during the design process. Evan is reacting to a proposed plan of action from Jill. Jill has suggested that due to the relationship she created with a local, non-profit bike shop, each team of three to four students would be able to design and draw up schematic plans for a bicycle they would like the bike shop to then build.

- Evan: For me, if I try to pull that off, within this context…I'm not saying you couldn't do it. You know what I mean?

Evan is clearly not interested in pursuing this logistically challenging proposal. Evan sees students on a cyclic basis, for three days at a time, every other week. He also typically has class sizes of 30 or more. For him to plausible pull off orchestrating 10 small teams of students each creating a bike seems unmanageable and impractical. Jill, the classroom teacher could 'do it', but for him it is not going to work. Here Evan's classroom realities have limited his ability to see as a designer, at no fault of his own. The team, which consisted of three STEM specialists like Evan, unfortunately did not ever consider moving forward with Jill's innovative and challenging idea. It was a logistical nightmare and inherent with classroom management issues for them.

The pull of previous classroom teaching experiences, as evidence here, is in play when asking current classroom teachers to design curriculum for their own and an outside audience. These exemplars, and the others that allowed the theme to emerge from the data, denote just how likely teachers are to bring up and consider past teaching experiences during the design process, whether it be detrimental or beneficial.

Teaching identity. Teacher identity was a prominent aspect of Team RF. The split in makeup between Team RF, classroom teacher versus science specialists, allowed for teacher identity to emerge as a significant theme during design conversations. The vast amount of literature discussing teacher identity and the likelihood of future design teams consisting of teachers with varying specialties justifies the inclusion of the following interview responses and exchange. Evan and Derek begin in their individual interviews discussing how identity has played out in their team, along with their previous experiences using a popular engineering education curriculum in their classrooms.

- Evan: She's (Jill) practical too but she's a classroom teacher, so she's got…I think because we come from, the three of us in the original team, come from the same school and EiE is our foundation. She's an elementary generalist and she teaches…

  Author: Every…

  Evan: Yeah. So her, her expectations and the way she's going about it is very different than the way I'm thinking as a STEM engineering-focused person. And um…so that's something were just resolving, we're trying to all figure out.

Below, Derek is discussing a proposed structure for consideration during the unit.

- Derek: Yeah. It's the…the structure's very different than what we typically teach. But we're…I think I'm very used to…I'm maybe too used to the EiE lessons so…

Derek and Evan have both taken on a certain identity since they each became STEM specialists two years ago. Their identity, and what they do in their classrooms, is different than that of a classroom teacher and it is largely a result of their participation with a familiar curriculum that they have each used. Past teaching experiences are noteworthy for teachers to be aware of and consider when brought into a curriculum design space.

Jill, who has been characterized as being different than the other three members of her group can be seen in the following teammate exchange and interview response taking up her identity as a classroom teacher. To begin, Jill and Evan have the following exchange involving the use of content standards in the design process.

- Jill: When I think of standards, I think of something that guides me. Guides that may have something I want to include. I don't feel like I'm limited to just what the standards say.

  Evan: You're not limited to it, but it's kind of the foundation of why you're doing what you're doing.

Being a veteran teacher, in a gifted and talented public school has given Jill some freedom in her classroom that Evan appears not to have. Jill, during the PD, was described by her teammates as being ‘amazing’ and a ‘superhero’. She told a long story about a past classroom experience where she had managed to salvage around a dozen old bicycles that her and her elementary students spent three to four weeks learning about and repairing for students and their families to use. The other members of the team were astonished that she was able to have that amount of time to work on a project of that nature with such a weak connection to any particular set of content standards. Jill brought this identity into the design process and continually brought up new ideas that she had toyed around with before in her classroom that she felt could be used in the new unit her and her team were designing. However, her partners were more reluctant to step into new territory, given their past identities as teachers. Jill, was perplexed at times by her team’s lack of willingness to move forward with any of the ideas her or others would suggest.

- Jill: It seems like they're worried about the (content) level, both in terms of…will the kids understand and can we do something that's a fifth grade standard in a 6th grade classroom and vice versa.

  Author: So you guys have had conversations about these things?

Jill: Yeah. I…I think because they're science specialist instead of just a classroom…

Author: Classroom teacher…

Jill: That they're more worried about…they see them (the standards) as maybe more structural and a constraint; whereas I see them more like, a part of a whole. I'm not so worried that…

Jill's identity, and her experiences working with a different population of students allowed her to suggest activities and labs that were occasionally perceived as being too challenging for the other members of the team's students. Jill, in this situation had her identity, and her skills as a designer, impacted by her past experiences with her students. Conversations about students during the design process were prominent and will round off the theme, *teachers past classroom experiences*.

Student abilities. Teachers have past experiences with students that impact how they perceive student abilities. When you take a teacher out of the classroom and ask them to be curriculum designers, he or she will inevitably bring their students along for the ride. Below, are instances where teachers would bring up their students and past experiences with students that were on their mind during the design process. Exchanges or interview responses involving students were predominantly pessimistic. Exchanges and interviews typically discussed students, and their abilities, as not being capable of being able to accomplish the task someone was proposing. To start off, Evelyn below describes the nature of attempting to translate engineering into an elementary classroom.

- Evelyn: Like, before I was in EngrTEAMS, I was like…I have no idea how to teach engineering. It was that part…so like coming here and thinking like, 'oh this is actually how an engineer thinks about these things'. Not to mention, how can you relay that down to a ten year old?

Teacher, no matter their years of teaching experience need help translating the type of work an engineer does into something they can imagine their students doing. Without help, it is almost as if any innovative or challenging activities are beyond their students' reaches. Evan describes this below.

- Evan: One of the issues of engineering that we were struggling with is, and are still kind of, is how can the kids actually engineer a bike? How can they actually do something that technically rigorous?

The struggle comes about due to the complex scientific understandings and challenging mathematically analysis one assumes real engineers must apply during their day-to-day work. Teachers realize this and when they begin looking at the grade-appropriate content standards, find themselves reaching up towards more complex scientific and mathematical concepts. Derek explains this below.

- Derek: We may be able to modify…easy. One of the things we've struggled with is keeping the science content at that fifth grade level. We keep wanting to go a little bit higher. For example, with the measurements, like were talking about acceleration, that's beyond what our students can handle.

Derek's team could have used acceleration as a source of measurement while discussing motion and bikes, but this particular science concept is beyond his elementary classroom. His students therefore could not handle it. Content standards alone, were not the sole consideration teachers contemplated during the design process.

The materials and ability to work through a complicated design challenge were also actively discussed and brought up, revolving around teacher's perceptions of student abilities. Below, Sammy and Nick discuss a propulsion method for the rescue vehicles their students will be working with.

- <u>Sammy</u>: If we wanna go there, that could be easier for them.

  <u>Nick</u>: Than the rubber bands?

  <u>Sammy</u>: Tools rather than motors. Or if our kids are getting frustrating or struggling…for kids that need to differentiate the materials, a little bit lower for them.

The team needed to come up with a base vehicle and reliable propulsion source that could then be manipulated based on students' designs. Sammy, having never used electric motors such as the ones the team was considering, suggests that motors may be frustrating, and that her students could possibly struggle with them. She quickly alleviates this dilemma in her mind by stating she could 'differentiate' the level of the materials for her students.

A similar exchange, this time amongst Team RF, also has the team discussing the ability of their students to take on a proposed lesson involving gears and gear ratios.

- <u>Derek</u>: I'm thinking like…what will students want to make modifications to. I think this part of the bike is more likely than this part.

  <u>Evan</u>: Gears are complicated.

Michelle: So we start with balance and motion?

Evan: It's hard.

Derek: It is.

Evan: Understanding, being able to identify the little gear with the bigger…and the combinations.

Derek's students are central to his thinking as a designer. When considering which lessons should be used leading up to the design challenge, he considers the likelihood of his potential student choices during the design challenge. He ponders, will they make changes to the wheels or will they adjust the gear ratios; and he does so by considering what choices his students will typically make based upon his past experiences in the classroom.

The following exchange adds to the less than optimistic view of students' abilities during a STEM-integrated unit. Team RF is again considering what to do with the bikes students will potentially be designing for their real-world client. Can each individual team, handle modifying one aspect of the many parts of a bicycle, to then be brought together for the class to complete as a whole?

- Jill: I'm still not sure if it's better to have the whole class make one modification. It seems like a lot to have (different) groups making up (different) modifications. That's a lot.

Derek: I think that's too much to ask of them.

Both Jill and Derek are not sure their students are capable of doing this. Whether or not they are also questioning their own abilities to orchestrate such a large, open-ended project is uncertain. Jill had previously mentioned a similar project she took on before, indicating perhaps she could take it on again, while Derek has reminded the team about how 'materials-heavy' the bike unit would be. Even when teachers weren't directly considering their own experiences with students during the design process, they were still considering how students would engage with their units.

Sammy in the following exchange consulted Mary, an EngrTEAMS PD content leader, and coach for Sammy's district she knows. Sammy and her team were considering a variety of science concepts for their design challenge involving rescue vehicles and the terrains they would navigate (sand, water, ice, etc.). The question of what content was appropriate for their students was up for debate.

- <u>Sammy</u>: So Mary's recommendation is that they don't need to know gravity till eighth grade. But, she thinks it will serve them well if they can name it in fifth grade, if it will help with this challenge. Buoyancy would be too complicated. Inertia, they're gonna get later but, their not ready for it now.

  Nick: Right.

  <u>Sammy</u>: So gravity and friction are her recommendations.

  <u>Nick</u>: Okay, as far as force?

  <u>Sammy</u>: Yes.

Here, Sammy was uncertain about a specific set of science standards so she sought out someone she knew and was confident would be able to help her solve the team's problem. Central to her concern were students, and their abilities. Attempting to bring in the appropriate content standards to a STEM-integrated curricular unit is challenging. Teachers are concerned about what's too complicated given the nature of the types of design challenges their asking their students to engage with in the unit. Will their students be able to successfully complete the design challenge and learn the intended concepts while engaged in the process or explain their thinking after the fact?

Three examples from Team LD all connected to the team's concern about their student's ability to engage with the content they identified for the unit. Evelyn can be seen below discussing the purposes for the activities leading up to the design challenge below.

- Evelyn: They (students) lack a lot of background knowledge and background experiences. So were giving them all these as a way of building up their background for the engineering design (challenge).

Evelyn has determined that her students will not be able to participate in the tool design activity they have decided to place at the end of their unit related to landmines. She justifies this choice based upon her past experiences with students in her classroom. One last excerpt, this time from Rita, as related to a question the team had about student ability related to displaying data and data analysis.

- Rita: Maybe they didn't learn it in their (previous) classroom. So it was taking us more time to do some of the graphing and data analysis. Because it was like (their) first exposure for some of them. So this year we're doing fourth grade (math) standards. So hopefully…they've had that experience and we can review it rather than teach it.

In considering what grade-level standards the team would use for the unit the team wanted to move a grade down. This was a choice made for two reasons. The first being that the team knew they would be implementing at the beginning of the school year so it made sense for them to 'teach' content standards from fourth grade rather than fifth. Secondly, the team's past experiences working with students. Evelyn has integrated math into her science classroom before, and this experience indicated to her that attempting to give students 'exposure' to math for the first time was challenging. She therefore hoped to just review data analysis with her students, relying on the students' previous experiences in math class.

This last exchange is between Rita and Evelyn, who on this occasion were working with Hank instead of Abby. Abby was not considered amongst the group as a science expert, as previously mentioned, and Hank was brought in to help the team consider a meaningful way to measure force during the design challenge.

- Hank: I know you don't want them calculating forces and measuring the distance from the fulcrum and finding out how far the ball went. That might be too much.

  Rita: Overwhelming.

  Hank: But if you could do one of these things, then reason about the other ones, maybe that's more in reach for your students?

  Rita: Probably.

  Evelyn: Yeah.

This last exchange is important, and ties in with the study's larger theoretical assertion related to encouragement and innovation. Hank encouraged the team to try something different. He came in with a plausible solution to the measurement problem the team had uncovered, once they realized the importance of forces when discussing detonating a landmine. Throwing a ball of clay with a launching arm that lands in the general area of a potential landmine is pointless without accounting for the amount of force that must be applied to trigger detonation. The team knows this; they have extensively researched landmines and real-world companies that take part in this type of work. However, Hank's suggestion, even a minimized version of it, is never truly taken in to consideration. A deeper look at the team's decision to not include force or a measure of force in their unit's final design challenge will be discussed later in the section, under the theme *embrace complexity, and ambiguity*.

A last excerpt from Evan points to a bit more optimism about the unit's potential, in relation to his students and their abilities.

- Evan: And often times kids don't care once they figure…I don't care how it works. I don't know how I balance. They don't have any idea about it. But at the fifth grade level, it might be a great time for them to try and figure that out. Why is it, that when you go on a two-wheel half-inch piece of rubber…how is it that you can stay up on that?

Evan is excited about bringing this unit in at a fifth-grade level. His students, having driven bikes for a few years, but never really being asked how exactly this works provides Evan with a spark. He could see the possibility of the unit hitting at just the right time. This, and all the previous excerpts and exchanges, ground how prevalent a teacher's past classroom experience is on the design process.

Theme 3: Past experiences with curriculum and professional development activities and supports. In addition to bringing in their past experiences from the classroom, teachers also bring in their experiences with curriculum they have used in past, previous curriculum design experiences, and PD experiences focused on curriculum development. These experiences are brought into the design space and when taken into consideration under the larger category *Teachers First, Designers Second* illustrate the strain it places on teachers during the process.

Professional development influences. It is becoming more common for teachers to be affiliated with PD projects that require participating teachers to create a final product such as a curriculum. The next two themes will illustrate how teachers take up or disregard some key aspects of a PD project. Again, teachers predominantly engaged in the process as teachers first and designers second.

Team EttR, coached by Nick, was highly influenced by the PD activities and supports put in place by the PD that the curriculum writing was embedded in. In total, there were four exemplar pieces that were reiterated or actively discussed by all members of the team during the design process. The last three aspects (creating a rescue vehicle, providing a girl-friendly context, and not getting lost in the build of the final design challenge) were taken up by the team in the design of their unit with slight modifications. To provide context, the PD leaders made a change from year one to year two which is discussed first.

It was a concern of PD leaders and facilitators during year one that too many teachers had either come into the PD and design space with a 'pet idea' that they wanted to write around and that there was a 'copy-cat affect' in regards to activities from the PD and teachers' designed curricula. During day one of the PD, the following announcement was made to the whole group regarding this issue.

- Whole Group Audio: Angela (Day 1): I know a lot of us as teachers have that pet project, the thing we love. This is how we're taking this…the view we're taking for these first two days….these are kind of like projects that could represent the thing that you love to do that maybe doesn't hit the content particularly well. But you know the kids love it so I'm gonna do it. So the idea is to start with something that could represent that sort of thing and then were gonna work on making it better thru the next several days.

To intervene with these two observed behaviors, there was a concerted effort to require each team to seriously consider developing three separate ideas and then come to a decision point on one of the ideas as a team. This strategy was one that was commonly discussed amongst all the teams. Team EttR was more influenced than the others, as will be seen below.

Three ideas. The process of coming up with an 'idea' for a STEM-integrated unit for an elementary classroom is challenging. The requirement to generate three potential ideas prior to moving forward is even more challenging. Team EttR during their individual interviews without being prompted brought up the requirement to have three ideas developed during the curriculum design process. Nick, the team's coach, stated that, "Forcing us to pick three ideas and think about those three ideas was important. It was also important to come together as a team in choosing just one idea." Sammy mentioned how this aspect of the curriculum design process influenced her.

> Sammy: I think it was really important that, even though I was really excited about the rescue vehicle especially the context of it, that I really was able to step back. I actually really liked the rocket…I really tried to work on it in my head. Then we had to develop the other two ideas. That's not something that I would do in my own practice.

Sammy developed the rescue vehicle idea for the team, but as she stated she also tried to develop the rocket idea. If she had not been working in a team, she would not have developed two other ideas. She uses the phrase 'in my own practice'. In this instance, she recognized that the PD and the team-based nature of the curriculum development process influenced how she had been generating and developing ideas. She realized that had she been on her own she would have done it differently. Nathan was less in tune with the three ideas requirement. His response is below.

> Nathan: We came up with three (ideas). What was helpful was Angela saying that you need to come up with 3 ideas, 3 main ideas. From those three (ideas) come up with key elements that would work. I think this is what we did… and then list the advantages and disadvantages (of each).

This was an important point in the design process for the team. Nathan does not easily recall the event and notes 'I think' that is 'what we did'. Matt who was more engaged during the design process picked up on the importance of developing and considering three ideas.

Matt: This year I think, especially during the early phases of the curriculum design, I remember Angela one day said that you had to have three different ideas down. We eliminated one, so the early activities that we've done this year seem to have been a much bigger focus compared to last year.

There are two significant points to further discuss here. Both are connected to the larger conceptual category involving facilitation. First, teachers do not have many chances to develop multiple ideas for consideration in their classroom. They typically find one idea that can possibly work and go with it. This realization during year one of EngrTEAMS highlights the reality that teachers initially enter the design process as teachers. The second significant point is that the team of teachers in Team EttR chose to mention this aspect of their experience during the curriculum design process as being significant. It was significant to them because they came into the process as teachers and when asked to come up with three ideas it was noteworthy. Doing this was different, because it was not something that they typically did.

The last three aspects of the PD that influenced Team EttR all were sprinkled into the team's final unit idea. Recall that the team was interested in developing a unit that asked students to design and build a rescue vehicle that could traverse varying terrains during a rescue mission (e.g. stranded flood victims). The hovercraft idea was initially brought to the team's attention during one of the physical science breakout sessions Nick noted that, "Were doing something that's building off of one of the things that Hank prepared for us." He went on to say, "I think that experience was a big one obviously, resonated with people in the team". Matt, who spent a majority of his time working on the build that students would be engaged in, when asked what ultimately lead to the team deciding on the hovercraft idea stated that is was one of the, “little hands on things (we did) as a whole physical science team”. The team picked up on the novel idea of using plastic compact discs and small balloons as hovercrafts that students could then modify while thinking about and discussing the concepts of friction, force, and motion. Hank, who lead this activity of the physical science PD, wanted the teams of teachers to focus in on the concepts being applied during the modifications and not the build of the hovercraft bases. The teachers in Team EttR were also concerned about this aspect of the build for their own classrooms due to the possibility of students becoming too focused on the build. This came out during the following team exchange with Laura, one of the project’s principle investigators.

- Sammy: We also like giving them the choice of three base vehicles so that we keep our focus on the standard and not too much the build.

  Laura: Yep. Okay.

  Nick: It’s more about understanding the forces rather than building the car.

  Laura: And that's why we fussed so much about the cars you used during the last day with Hank. Otherwise you spend the whole time fiddling with the axels…

  Sammy: Yeah.

  Nick: Right.

These three examples from Team EttR do not overtly jump out as indicating that the participating teachers engaged in the design process as teachers first; but does provide evidence that they were considering their own classroom contexts first, rather than others.

There is no fault in doing this. Teachers were treated as teachers who were designing a unit for their classrooms, not necessarily designers. They therefore engaged in the curriculum design process as teachers. Conversations, as previously discussed, were tailored around their specific classroom contexts and students. By bringing in various aspects of the PD that Team EttR adapted for their unit and their classrooms, I am attempting to demonstrate the practicality and logic the team was exhibiting while designing their unit. As Matt discovered during the build, finding a true design challenge for students to participate in was challenging. When the team discovered a potential idea that had been vetted already (e.g. the hovercraft design) they ran with it and tried to find a way to make it work for their contexts and their unit. One last example, related to the context of the design challenge that the team took up will again exhibit the logic of adapting something from the PD to the unit the team was designing.

- Matt: We have talked more about the boy versus girl because of some of the stuff…like girls might not be so engaged with making fast cars.

  Author: (Laughs)

  Matt: So we've had to provide a context that students are helping other people and hopefully that will help the girls buy in a little more.

  Author: Not just making it go fast.

  Matt: Right.

Matt and the team frequently discussed the value of not just having students design a car that would go the fastest or the furthest. This may not have been considered, had the team not been exposed to an activity that focused on engaging all learners (including girls), into STEM activities. The team saw the value in engaging more learners in their classroom and justly picked it up when designing their unit. One last example that illustrates how the PD supports and activities are influential on teachers during the design process comes from Team RF.

Derek and Evan are attempting to justify the possible decision to allow students to only redesign one aspect of the bike, rather than completely designing an entire bike.

- Derek: Were trying to redesign some aspect of it (the bike).

  Evan: Yeah, when our engineers were here, standing there, they were saying that's what a lot engineering is.

  Derek: Yeah, and they said most engineering is redesign?

  Evan: Redesigning…taking something and making it better. What was it they said, engineers…there was…engineering is redesigning and making things better

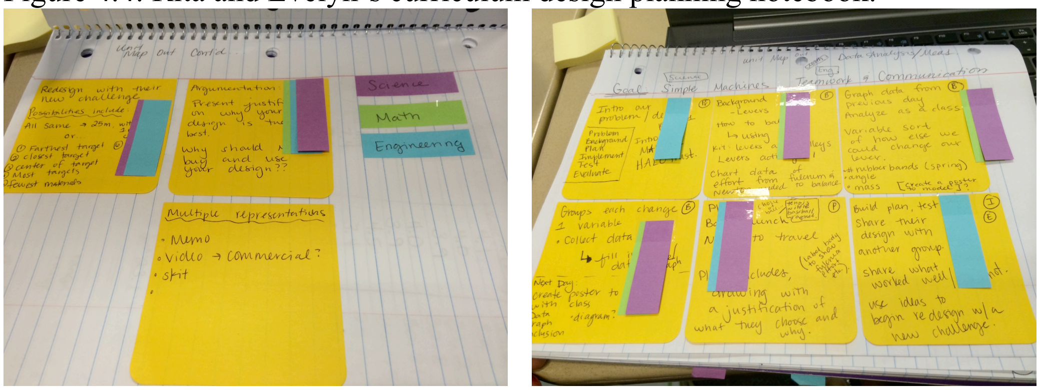
  Derek: Yep.

This exchange ties together the theme very nicely. Both Derek and Evan were influenced by a specific support provided by the PD, a resident engineer they could bounce ideas off of during the curriculum design process. It also connected to the team's concern about the unit being 'materials-heavy' as a result of bringing in bike parts and tools to assemble working bikes. The team, aside from Jill, had never taken on a design challenge that required them to manage materials and students on a level such as this. It was therefore justified, based upon their interaction with the resident engineer, to have students redesign one aspect of a bike, rather than designing an entire bike. This pragmatically and logistically makes sense. Having 10 student groups independently designing and building a bike from scratch would be challenging. It was clear that Evan and Derek realized this, were slightly concerned about trying to manage this in their own classrooms, and justified a different route of action because of the PD. Transitioning to a different support from the PD that was not as easily adopted will illustrate a similar but different point.

Professional development support. Features of the PD likely to be taken up by teachers during the design process were activities that could be easily adapted to their classroom (e.g. design a hover craft). This 'show and tell' style of PD is common and allows for teachers to easily move an activity they have experienced in PD into their own classroom. Other features of the PD, not directly related to a classroom activity are not as easily adopted or appreciated. This is especially true if the feature or support is one related to curriculum design given that teachers do not typically think of themselves as designers. It is also uncommon for teachers have the luxury of planning and designing a unit months prior to its implementation.

Recall the unique makeup of Team LD, two teachers with a previous relationship during the second year of EngrTEAMS, who had a consistent view of the purpose of the unit they were writing. This relationship and previous experience writing a unit during year one of EngrTEAMS presented the team with a paradox. The issue related to the 'backwards design' philosophy of UbD, a strategy that was put into place and heavily targeted prior to the curriculum writing days of the PD. Rita and Evelyn however, chose not to utilize the supports posited by UbD, such as writing big ideas and essential questions. Instead, the team drafted nine lessons while following a daily planner they had created in Rita's notebook (see Figure 4.4).

Figure 4.4: Rita and Evelyn's curriculum design planning notebook.



The team did not see the point in designing the unit starting with the end in mind. Instead, as Evelyn explains below, the team put into place the strategy that they had used last year, and possibly one they utilizing during their unit planning during the year.

- <u>Rita</u>: We had our ideas on note cards and we added (color) 'flags' for science, math, and engineering. Then, for each day, if we were meeting a science, math, or engineering standard (we would add a colored flag). This allowed us to see if lesson and the unit had any gaps. Also, when we were writing lesson plans, we'd make sure we were including those standards.

The team put into place a strategy that essentially replaced the UbD documents they were supposed to use prior to drafting the unit. This does not mean that the team did not eventually complete the UbD document; it just means that they considered it important enough to do but in a different way. After they had drafted each individual lesson and created an accompanying presentation that would follow along with each day of the unit, the team completed the UbD document. Abby, the team's coach, on several occasions brought up the team's decision to write lesson plans first, but never encouraged the team to go through the process of writing big ideas of essential questions beforehand. Instead, she supported the team to use the strategy they had created.

- Abby: So on paper we wrote down our big goal with the simple machines and our engineering goal, which is teamwork and communication. Then we wrote the math goal, which is data analysis and measurement. So whenever we would get off track, 'cause that seems to happen, we can look at the big goals (ideas) on the paper.

Evelyn and Rita had used a strategy to write curriculum before. They did not see the point of using a new strategy they'd only heard of before when they had one that already worked. The team, as evidenced in Figure 4.4, then 'drafted' lessons similar to how a teacher planning a lesson the day or week before would do so; by writing out short sentences on a sticky note. Bringing in the actions of another team will round out the theme and further demonstrate how the category teachers first, designers second played out within the theme of PD influences.

Team RF largely resisted utilizing the UbD 'backwards design' philosophy during the curriculum design process. Whether or not the process was unfamiliar or confusing to the team is uncertain; but what was noticeable was that the team needed some driving document to guide them during the design process. The team was torn between a wide array of content standards and were continuously discussing skills that the students would need to be applying during various activities. They were unfortunately reluctant to carry out the unwrapping process to find the skills and concepts they could not come to agreement on. Hank was well aware of the team's need to utilize the benefits of UbD, but never forced the team to actually use it. Hank stated this during his individual interview noting the following.

- <u>Hank</u>: I don't think they value my emphasis on standards. I don't get that feeling yet (laugh). Derek has a little bit had some comments like yeah, we really do need to come back to this; but that's pretty much all he said and no one else in the group has run with it.

Later on in the interview, Hank explained with more detail how the team had been attempting to design the unit.

- <u>Hank</u>: I'm asking questions right now because I…am getting some resistance on the plan of picking a standard, unwrapping it, and designing an activity. They are not feeling that.

  <u>Author</u>: They just want to design the activity.

  <u>Hank</u>: They came up with a slightly different approach. They picked a wide array of standards, pretty much all the force and motion standards, (and said) we wanna do something in here. So now, let's talk about an activity and then once we tack up the activity, we'll see which of these standards were really actually doing. So it's a little bit of a back and forth.

Despite the push to have teachers go through the process of unwrapping the content standards they were interested in pursuing, the team exhibited some 'resistance'. Hank casually states they are 'not feeling that'. Hank then indicated his team's preferred strategy, which one could argue is similar to the one put into place by Rita and Evelyn.

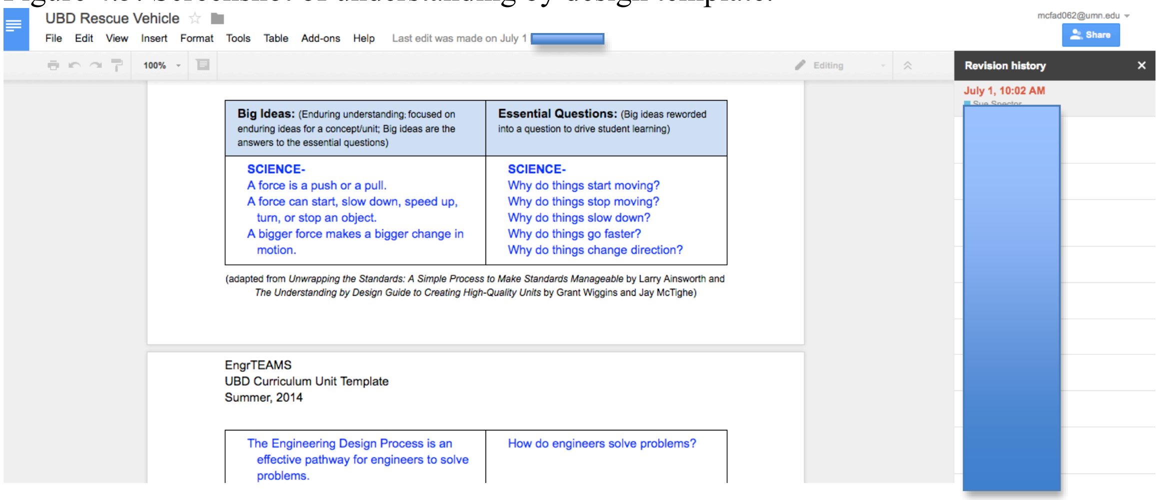
The team wants to talk about the activity, 'tack it up' on a piece of poster paper and then see where it aligns. In regards to curriculum design, you could postulate that the team is initially taking up a practitioner's point of view (i.e. what will the classroom activities look like when implemented). Team EttR took a different approach to the UbD curriculum design process, but still did so while indicating that they did it as teachers first and designers second. Hank on many occasions tried to get his team to use UbD as a curriculum design strategy. He attempted to get his team to use it to help them with their multiple concepts and skills problem.

- <u>Hank</u>: Hopefully were going to be able to design the activity to support that data collection and analysis right? I guess what I'm asking is, what's the meat of this, what are they doing that you say 'ah ha'…some science and math is happening here. What do you see your students being able to accomplish with this activity? We will unwrap and design this activity perhaps around that goal. Is that clear as mud? I don't know if I'm making any sense at all…

Hank's confidence in this declaration is not strong. He questions it with a humorous remark near the end. Hank recognized his teachers' tendencies, drafting lesson plans first for classroom use, and unsuccessfully pleaded with them to try a different strategy, a strategy that a designer would put in place first.

Team EttR exemplified a negative case in regards to the utilization of UbD. The team was eager to talk about the big ideas and essential questions of the unit and also looked for approval of their written work related to the UbD templates they were provided to complete prior to drafting any lesson plans (see Figure 4.5).

Figure 4.5: Screenshot of understanding by design template.



Nick early on in the idea generation phase proclaimed the importance of using UbD with the team.

- Nick: I would say at some point…I would like to…the UbD is…this is way down the road but…UbD is really an important document. But for our unit we also wanna have with each lesson just a simple overview of the lesson.

This announcement to the group came up as Nick was attempting to alleviate some confusion on the part of the team related to the purpose for filling out the UbD template. During his interview, Nick acknowledged his appreciation for going back and forth between designing a unit and the content standards, a key premise of UbD.

- Nick: The fact that we are starting with the standards and then going to a design challenge and then going back to the standards and then going back to the design challenge; that juggling back and forth between the two… makes it open-ended and rich and full of context. But at the same time it brings it back to the learning goals.

It was clear that Nick valued the UbD process for creating curricular units and reiterated this to his team. What was interesting was how his team responded to his actions and praise of UbD.

The team was able to write up a completed UbD document for the unit. Sammy and Nathan did this. What was interesting was the team's need for approval of what they had written. Given Nick's experiences using UbD in the past, the team looked to him for approval.

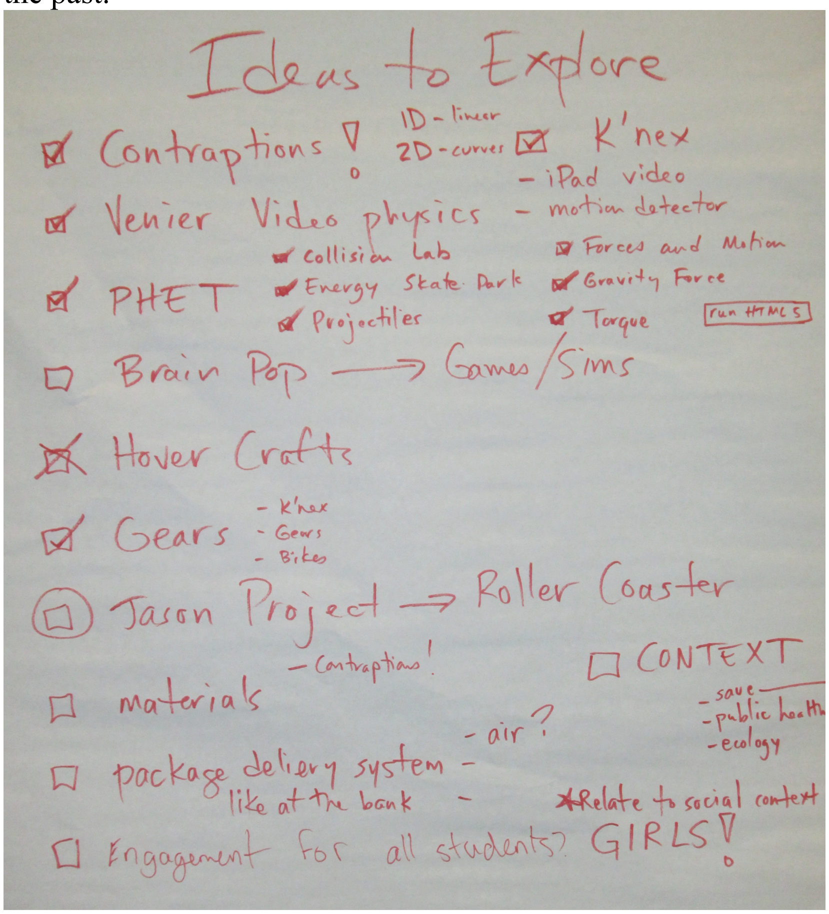
- Nathan: So I don't get too far out (on the UbD template), can you take a look at the big ideas and essential questions for the math and just say…am I on the right direction? Is this what I'm supposed to put there?

  Nick: Um…I think those are all, that's good. I think they're like definitely…

Sammy and Nathan are teachers. Having to think about, talk about, and draft out a guiding document like the UbD template provided to them is different than what they are accustomed to. Nick was noticeably unprepared to provide direct feedback on what Nathan had written. He states they are 'good' and then trailed off. Nathan then proceeded to unwrap the remaining math standards. Nick's overseeing of the team's UbD document and the team's unfamiliarity with creating and utilizing a strategy like UbD again hints at the reluctance of teachers to jump into their roles during the design process as designers. Instead, their varying past experiences in the classroom and lack of familiarity with writing for an outside audience comes into play. Finishing up the theme will be the influence of past curriculums on teachers during the design process.

Past experiences with curriculum. Each team at varying points of the design process brought up and actively discussed or referenced curriculum materials they had used in the past or found online. Figure 4.6 contains a list of 'Ideas to Explore' from Team RF that contains examples of the past curriculum resources the team had used in the past and were considering during the design process.

Figure 4.6: Team-generated poster containing curriculum resources teachers had used in the past.



This last set of exemplar exchanges highlights how each team utilized outside curricular resources during the design process. It also builds upon the argument that teachers are influenced by the PD supports and activities they are surrounded by albeit slightly different given that the influences they interacted with were curriculum resources personally identified and brought into the curriculum design process.

Team LD drafted more lessons than the other two participant teams combined. Part of this can be attributed to the team's makeup and characteristics, which has already been discussed. The other driver that allowed the team to quickly move through the design process was their reliance borrowing for previously written and used curriculums. Rita during her individual interview indicated the team's reliance on the "Foss Kit" they've used in their classroom before related to variables.

- Evelyn: I think were thinking about using some things that we've done with like…Foss to help teach like the different variables. Or the different variations of them to help talk about…

Here, she is outright claiming that there are lesson ideas they are 'using' during the construction of their unit. The following exchange provides a better idea of how nonchalant the team was about their use of other curriculum resources. While looking over the materials list for a previously started lesson, Evelyn comments that the material list is already completed and proceeds to praise Rita.

- Evelyn: Oh, you already typed all the materials too. Look at you!

  Rita: Look at me go! Well it's easier 'cause I just basically had to copy a list.

  Evelyn: (laugh)

  Rita: (laugh) That's the easy part…

Here, Rita has offloaded some of the responsibility of designing the unit to another curriculum resource. This makes sense, since the lesson they are adopting is essentially the same. It also makes sense for a teacher to pick up on this because it is a time saver. When you do not have to make up a list of needed materials for a lesson it saves you time. A designer on the other hand may have not taken this shortcut and rather choose to consider the materials needed for the laboratory activity given the modifications put in place. The team referenced Foss Kit manuals often relying on them for vocabulary definitions, data measurement teaching strategies, and assessment activities. The team also leaned on other curriculum resources during the design process.

In the following exchange, the team identifies a strategy used by another curriculum to engage students in the engineering problem.

- Evelyn: I kind of like giving them the partnership…I like how Nature Inspired Design introduced theirs.

  Rita: Yep.

  Evelyn: They had just some documentation that showed the company, the problem, and their goal. I like the idea of sharing it from a story perspective. I liked his story.

  Rita: We could adapt it.

This real time exchange exemplifies how casual teachers designing curriculum will jump to and consider adapting curriculum resources from outside sources. This is what teachers do. They borrow, adapt, and make a lesson or activity work for their classroom context. The intellectual property rights of the idea are of ill concern. Teachers have a casual stance when it comes to adapting curriculum resources for their specific classroom, something that would be problematic for a curriculum designer. This last exchange from Team LD again alludes to how teachers will borrow and slightly adapt curriculum resources. Rita and Evelyn spent considerable time deliberating how to bring students into the engineering design process. Here, they consider using a model espoused from a curriculum Evelyn has used in the past.

- Evelyn: So this is an old unit I'm looking at. This one talks about engineering, but it's like written for teachers. It went through and it talked about…so were going to use the engineering design process. It's a process of looking at a problem, so our first step in this process is talking about the problem. So if this is the model we wanna use, it makes sense to intro the problem at the beginning (of the unit).

The team was not sure if students should be introduced to the design challenge and overarching problem prior to learning a little bit about the context and some of the smaller problems that arise due to the larger problem (i.e. buried landmines). Evelyn states that it makes sense for them to introduce the problem right away as a result of what she's read from the other curriculum's background section.

The decisiveness of the team to simply adopt and slightly adapt previously written curriculum resources allowed the team to seamlessly move through the design process because much of the heavy lifting and time-consuming details were already accounted for. The team just needed to overlay the engineering context on top of the unit to complete its integration. It is not that the team did not draft their own lesson plans, they did. It is the fact that they were able to borrow ideas and 'lists' from previously used curriculum resources. The other major writing piece that the team engaged in was the creation of a 50-slide document that could be displayed during the unit's implementation.

This is a very teacher-centered action. It's uncommon for mainstream curriculum designers to include a pre-fabricated slideshow that can be used to compliment a unit when it's implemented.

Team EttR, as previously discussed, was entrenched in a materials dilemma related to their final design challenge. They were uncertain how to have students successfully design and build a vehicle that utilized various forces over varying surfaces. And while Matt spent a majority of the time tinkering with the materials, Sammy spent a considerable amount of time looking up and discussing how EiE used a base vehicle in a unit she had used before.

- Sammy: So I got this idea from EiE. It uses a base vehicle and I've used it in my classroom before when we try to keep ice from melting. I gave them a choice of different base packages for it. It works well, but it takes the focus off the building and puts it more on the standard.

She goes on further to discuss some strategies related to using base vehicles, reading from the EiE manual.

- Sammy: It (the manual) says it's important to discuss the properties of the base packages and the functions they do or do not meet.

Each of these excerpts demonstrates how teachers rely on previously written lesson plans and manuals during the design process of a new unit. While typing up lesson plans, Sammy's teammate Nathan even included a series of video segments he had used before in his classroom (see Figure 4.7).

Figure 4.7: Screenshot of daily lesson plan containing a teaching resource previously used by a participant teacher.

Before the Activity:
Prepare the materials within your classroom.

Classroom Instruction:

Introduction:
Today we will be learning about Friction.
"What is Friction?"

"Give examples of Friction."

Activity:
1)Begin the class period with the Bill Nye video on Friction.
2)Introduce the materials to the students.
3)Place students into small groups of 2-3.
4)Distribute materials in an orderly fashion.
5)Students will allow a large metal sphere to roll down a ramp and measure the distance it has traveled. Repeat 2 more times and write the distance in their Science Notebook on a table. Repeat for a small metal sphere and record again. Repeat with the small wooden sphere and record again.
6)Repeat these steps on a different surface to see the change in friction.
7)Use the data to solve for Mean, Median, and Range. Looking at the data, determine what type of surface allows for less friction.
8) Display information on a Line Graph or Bar Graph.

This phenomenon connects to the theme and overarching category it was placed in by demonstrating the actions of teachers during the design process in relation to other curriculum resources and by allowing one to envision the patterns of teachers entering the design space as teachers first and foremost. It is not that Sammy was doing something that she should not have been doing, even though she slightly indicated that she felt strange copying ideas from EiE.

- Sammy: Okay, so here's how EiE does it…not to copy it, but just to give us some background. This is how they make a cart with wheel and axel.

Sammy does not want to copy what was previously written, she just genuinely wants to know what some plausible solutions could be.

The next set of examples comes from Team RF. Two members of the team were very grounded in the engineering design process put forward by EiE. The team adopted these curriculum resources Evan and Derek became STEM specialists. Below, Derek and

Evan discuss the influence of EiE on their thinking to Jill who was uncertain of the integration model the team was sticking to.

- Evan: This is the way I think about it…the work that we do. It's the model that we kind of just adopted um…

  Derek: Yeah, we certainly adopted that EiE engineering design process.

Earlier, Evan explained to Jill just how the engineering process was supposed to work according to the EiE model he was referencing during the design process.

- Evan: These are the parts of the engineering design process that they need to implement: ask, imagine, and plan. The preliminary background part gets the science (in there). Then they do some investigation of the systems of the bike to get some fundamental knowledge of the system that they're trying to innovate, change, or reinvent. That's generally what we do.

The team's identity issue, as previously mentioned, comes out here; but what stands out more so is the impact and influence of the EiE engineering design cycle. Derek and Evan's previous experience with EiE and this cycle remain with them during the design process. Any proposed deviation from this model or cycle will be troublesome given their comfort and familiarity with the EiE cycle. Interestingly, Jill challenges Evan and Derek's preference to separate the science and engineering design piece of the unit. Jill, having never used EiE, attempted to figure out exactly why the unit couldn't be more integrated and concise.

- Jill: So you're separating the science instruction from the…

  Evan: The science instruction comes before the engineering…

Jill: And I'm suggesting that we just overlaying them a bit.

Evan: Well no, we're doing the science in front, and you're saying…

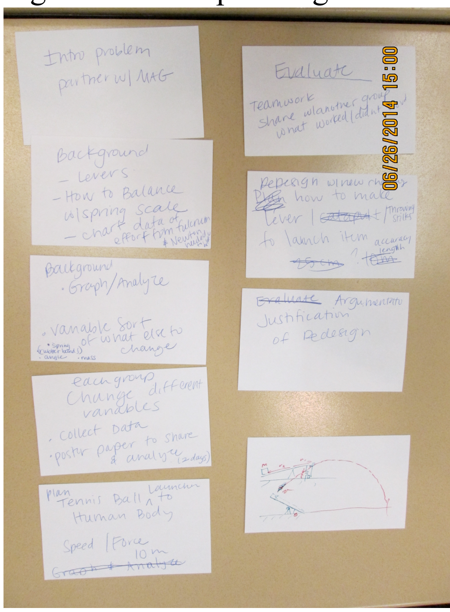
Jill: Well I think there's two ways of looking at the activities: one way is exploration or experiment…generating data that kind of stuff; but it's also like a chance for them to focus on the gear part of their design. That way they can start to make choices about how they want to configure the gears for their bike.

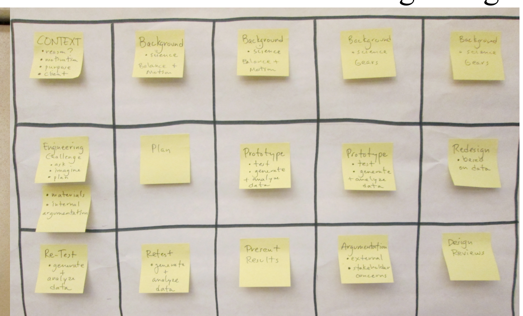
Jill's role in the group as a classroom teacher and not a STEM specialist put her in a position to question some of the assumptions about how an integrated unit should look. Evan, more so than Derek, was interested in transferring the model he was familiar with during the design of the unit. Despite the possible advantage of moving forward with Jill's plan of action and integration, the team remained planted in their EiE roots.

A teacher's past experiences needs to be taken into account during the design process. This theme and set of related sub-themes were put together to further develop the argument that teachers' past experiences with curriculum or supports put in place during the curriculum writing process are significant and worthy of consideration when asking teachers to design curriculum. It also brought in examples from the data the indicated the prominence of this occurrence, while also presenting the data in way that suggested teachers brought these experiences into the design space while thinking of themselves as teachers first and designers second.

Theme 4: Background activities. The category *Teachers First, Designers Second* is made up of one final theme and related data sources. All three teams ubiquitously discussed "background activities" [BA's] which was initially unveiled as an in vivo code. The inclusion of BA's in each team's unit is a culminating result of the previously discussed themes in the category. Figure 4.8 contains hand written and digital examples of each team's inclusion of BA's in their unit planning and lesson sequencing.

Figure 4.8: Unit planning documents for all three teams containing background activities.





IDEAS FOR BACKGROUND ACTIVITIES:

Force:

- Hover crafts
    - demo hair dryer hovercraft for kids
- Rubber Band Cars
    - diff size rubber bands (thickness, length)
    - measure force vs. distance or force vs. speed
    - observe # of twists vs. distance or speed
- Name that Force!
    - show kids diff. scenarios of objects in motion
    - students need to identify force causing the motion, classify as push or pull
    - draw a force diagram
- Some sort of basic lesson teaching that a force is always a push or a pull
- Changing mass
    - force stays constant, mass changes
    - what happens?

There were several examples of BA's across each team and as a result, only a select few from Team EttR and Team RF will be discussed here. Team LD also discussed BA's; however, this was previously discussed in relation to another theme.

Natural stopping points. An elementary teacher's urge to compartmentalize a STEM-integrated learning experience has many drivers. Uncovering these drivers is not the purpose of this paper; however, given its predominance across all participating teams in the study is worthy of discussion in connection to the larger category. A STEM-integrated learning experience may or may not be enhanced by neatly compartmentalizing the content areas that the unit consists of into unique disciplines: science, math, and engineering. However, there is a comfort that comes with teaching each content area separately. When teachers are asked to do something different, such as integrate multiple disciplines into their curriculum, there is a pull from the past that urges them to teach some science, teach some math, and then do some engineering.

Elements from each of the previously discussed themes were also coded when a section of data was coded with the tag *background* activities. This created a predicament when attempting to locate this theme in a specific category. However, upon reading and rereading the exemplar data extracts from each team, it became clear that the theme spoke to the category as a whole. To better illustrate how this theme emerged, a memo written early in the process will help.

- Memo (02/24/2015): The teachers in every team are coming against the challenging question of what integration is; what does it mean and more importantly what does it look like. They are ill prepared to answer this question and aside from receiving information, via definitions and frameworks, have not internally processed this knowledge. They can't transfer it to the curriculum design process. Integration never truly happens, it's coupled together as a science or math ‘background activity’ that is to be then applied or utilized during the design challenge. Is this what integration truly is? Is this what it’s supposed to look like? The answer of what true integration is, and how to best transfer this understanding to teachers remains elusive. There may be parallels with how teachers took on and up scientific inquiry, but as far as STEM is concerned, disciplinary silos remain in place. Science and math lesson, followed by engineering with science and math hopefully sprinkled in during the design challenge.

At this point of the analysis I was searching for ideas, categories, and directions to build on. I was trying to locate where BA's came from and what they meant. I had not specifically set out to answer these questions and therefore found no answers. However, I was able to apply the data from this theme into the category *Teachers First, Designers Second*. This first extract from Team EttR helped me locate this vast data set in the larger category.

- Sammy: We are thinking…we were worried about that and we think…that the challenges (should) have natural stop points. So for example, after the ice they (students) have to analyze and explain how the science informed their engineering design, you know check it that way. We are gonna have background activities that will help with front loading.

Sammy and her team had a large amount of lessons, labs, and activities that they felt could be used in their unit. A majority of the lessons they were considering had previously been taught by one of them in their own classrooms (e.g. Nathan's "Friction Tray" lab). These 'challenges' as Sammy calls them eventually lead up to the final design challenge. At this point in the design process, the team was envisioning a series of stations being set up for teams of students to engage with. However, as Sammy stated, they were 'worried'. A unit set around a series of stations like this could be described as organized chaos as each team would be progressing at a different pace. To alleviate this, Sammy suggested having 'stopping points'. This would allow for two things to happen: the first being she would be able to keep students in roughly the same place during the unit; secondly she'd be able to 'check' in on each team to ensure that they could talk about the science they were applying to their design. Ultimately she was concerned about classroom management and assessing student learning. It was evident from this extract that she is contemplating what the unit will look like in *her classroom* and is being influenced by her *past experiences in the classroom*.

***What is the purpose of a background activity*?** To get a better sense of the proclaimed purpose of BA's, two extracts from Team RF will help.

- <u>Evan</u>: So that's a day…so we're taking four days for the background. I think that's totally fine, yeah. You gotta have that solid foundation before they (students) can do anything that makes any sense for their design.

Evan is literally counting up the amount of days that will consist of BA's. He is doing this prior to actually drafting up any of the lessons or activities that will be considered BA's. He is speaking from experience: experiences in the classroom and experiences with other engineering curricula he has used. Students need that 'foundation' to move forward and to accomplish this it will take about 'four days'. Evan's thoughts about the purpose for a BA paralleled that of Jill.

- <u>Jill</u>: It's a collection of ideas, vocabulary words. Uh…ideas and vocabulary words…maybe a formula, maybe some information, maybe a hands on activity. I was seeing it; I was seeing these as the building blocks to get the kids to the point where they could be engineers. You have to "tool" them, so to speak, with the information they will need. That way, they can do the kinds of things that we want.

Jill's definition has similarities to Evan's. She moves a bit further into her thinking by revealing that BA's allow a kid to get to the 'point where they could be engineers'. For her, giving students these experiences allows students to be able to handle what's coming at the end of a unit. And what exactly is coming at the end of a unit is an engineering design challenge that her and her team have designed. These two extracts, when discussed under the category *Teachers First, Designers Second,* reveal how BA's are a culminating result of a teacher's past classroom and curriculum experiences. These experiences lead teachers down a path of designing curriculum with their own classroom contexts in mind.

Background activities became synonymous with planning out a unit's sequence of lessons. Teachers as well as support staff discussed BA's during the curriculum design process. The subtle and understood necessity of incorporating BA's into the team's unit can be seen below.

- <u>Nick</u>: The first experiment is basically like…do this, make it go in a straight line and then the actual design challenge is okay, now were gonna…is that right? Are we still thinking that?

  <u>Sammy</u>: Oh, to have this be a background activity?

Nick starts off by discussing a beginning activity for the unit that involves having students use small vehicles to give them an experience manipulating how a vehicle moves in a straight line. Sammy immediately picks up that the activity can be differentiated from the unit's final design challenge, even though both activities were similar. She states, 'Oh, I got it, it's a BA.'

Background activities have one main purpose: to provide relevant and necessary information for students to apply during the design challenge. The language use is of interest here because teachers would discuss the transfer of knowledge from themselves to their students in very simplistic ways. Matt, very bluntly states the purpose of BA's in his mind.

- Matt: Like to give them some background information on friction and forces…we're going to do some hands on stuff in the classroom for a few days.

Matt describes here that teachers will 'give' students information that they can apply at a later time. Background activities are needed in order for students to successfully engage in the final design challenge. The importance of having a final design challenge that students could engage with as a result of BA's was not only reiterated by teachers. Mary, a science coach with one of the partnership districts, can be seen below talking with Team EttR about BA's.

- Mary: How would they…what steps are you going to put in along the way so that they have a sense of like what a rubber band could do or what…you know? There are like these little learning experiences along the way that (could) help them (students) even get a sense of what's possible.

She uses the phrase 'little learning experiences', which is easily understood as being a BA. Mary's had influence on the team, having worked with both Sammy and Matt in the past. Here use of a phrase similar to BA, furthers the notion that it is an essential portion of a STEM-integrated curriculum.

Background activities were an important piece of the design process for each team. By providing examples from two teams, the aim was to give readers a more intricate understanding of the language use, thought processing, and actions of teachers and others during the design process. In locating the theme under the broader conceptual category *Teachers First*, *Designers Second* a final argument is made by providing data that speak to the inherent tendencies of teachers to come into the design process first as teachers, and then as designers. Moving on to the next conceptual category *Coaches and Professional Development: Facilitation* will provide a new layer of data and analysis that supports the study's primary theoretical assertion: *Encouragement to Innovate and Design for Outside Audiences*.

Conceptual Category 2 - Coaches and Professional Development: Facilitation

Coaching a team of teachers while they design a product for an outside audience in a set amount of time requires a coach who is skillful, experienced, knowledgeable, and focused. Walking into the process and being an outsider will not be advantageous to the team or the final product. Coaches in this study and the PD model as a whole espoused to support teachers during the curriculum design process by providing facilitation more so than inspiration. The use of the word inspiration here is significant as it relates to the study's larger theoretical assertion and more specifically the word *encouragement*. The argument that drives this conceptual category is that teachers need encouragement to innovate. Innovations are not easily discovered and encouragement to move into the new, the novel, or the previously unknown requires inspiration, not facilitation. The previously described conceptual category, *Teacher First Designers Seconds*, indicates precisely how important encouragement is because of the tendencies teachers fall into when brought into the design area. Without encouragement to change, explore, or innovate; teachers will fall into patterns typical of their past while primarily considering their own classrooms. Table 4.5 displays the category's underlying themes and sub-themes.

Table 4.5: Coaches and professional development: Facilitation

Theme	Description	Sub-Themes
Coaches (Facilitation)	Coaches typically took on the role of facilitators during the design process. In this role, they also served as experts and teachers while focusing their team's attention on the standards or concepts.	Focus on the standards/concepts, coaches as teachers and experts, coaches as idea generators, a coach's opinion matters
PD Models	Activities, teaching strategies, or ideas from the professional development that are borrowed by teachers for their unit.	Replicate PD or 'copycat'
STEM-integrated slogans	Phrases or words that transformed how teachers assessed the curriculum they were designing.	Apply science and math in the design challenge, no tinkering

There is nothing inherently wrong with providing facilitative support for teachers during the design process; however, given the unique challenges and circumstances team-based curriculum design presents, a more progressive approach may be needed. The aim of this category is to highlight the facilitative role that coaches and the PD model provided teachers during the curriculum design process primarily by examining the real-time conversations of teachers and coaches during the process.

Theme 1: Coaches as facilitators. Facilitation is a term similar to assistance. In regards to coaching teachers to improve their practice, some coaching models adhere to this facilitative role. The underlying premise is that teachers focused on improving their practice can benefit from having another vested individual to assist them on the way. The type of assistance can be figured out along the way, but ultimately the chance for improvement lays in the hands of the teacher not the coach. Hank, a member of Team

RF, was very attune to his role with his team and was open and upfront about his role during his individual interview. His view about his role while working with his team of teachers is below.

- Hank: And so what I try to do is to facilitate. That is to ask questions. Say okay, so you said this is about forces, what kind of data are students gonna collect here? Versus, what I could do I suppose is say "no", we're following this template damn it! We're gonna start with the standards.

Hank was very aware of his potential power in the team, and was considerate of what he said to the team during the design process.

Hank: I am figuring out where this line between, the hands off…not the hands off coach, but the coach that doesn't authorize ideas.

This gives light to his role as a facilitator and not a leader or authoritative figure. He was not 'hands off' and he doesn't give his approval of any 'ideas' the team is considering. Hank's team was very aware and appreciative of his role. Their individual responses about Hank and the role he took on are below.

- Evan: He's always looking for ways that he can support what you're doing he'll take an idea…a little grain of an idea and he'll go (with it).
- Michelle: It's fun…and he kind of guides us with what's going on.
- Jill: Hank has been really good with a lot of the…with keeping us on track with the project, like how were supposed to be going about things.

Each of these extract provides evidence of the facilitative role Hank took on with the team. He 'kept them on track', 'supported' them, and 'guided' his team during the design process. From a coaching perspective, Hank is doing exactly what he has been asked to do. He is getting the team to clearly articulate their thoughts and language in an attempt to have his team focus on the learning that should be occurring because of the unit they are designing. When Hank asks questions, they are intended to be a jumping off point for his team. His questions should expand their thinking and force them to articulate their thoughts to the group. Below, is a quick exchange between Hank and Jill where he quickly jumps into his role as a facilitator.

- Jill: What's the science of the bikes?

  Hank: Good question.

  Jill: It's gear ratios and all that.

  Derek: Simple machines.

  Hank: Maybe we gave you a handout that told you what the standards were.

  Derek: (laugh)

  Evan: (laugh)

Hank was a facilitator. He asked questioned and wanted his team to come to self-supported decision points. Above, when Jill asked a question, he did not answer it, rather he pointed out that the team had been given a handout to help them identify the main concepts of the unit. Hank was unsure at times of his role and how it was being perceived. For the most part however, the team was appreciative of his role as evidenced in the below team exchange.

- Michelle: I think you…I think you questioning stuff makes us good though.

  Jill: Yeah. Don't question why you're questioning.

Michelle: No. Your questions are good.

Derek: True.

Jill: And don't question how your questioning is received (laugh).

Taking a step back, it is clear that everyone on Hank's team was aware of his characteristic actions. The other two coaches also took on a similar role; however, Hank and his team more eloquently discussed how this role emerged. To further explore how coaches from all three teams played the role of facilitators, a look at some exemplar data sources and analysis will follow.

Focus on the standards/content. For coaches engaged in curriculum design with a group of teachers, the standards provide a foundation upon which their questions and focus can stand. Coaches across all three teams would continually ask their teams questions that were focused on the content standards they were trying to hit. Below, Nick's response gives an idea of just how central the standards were central to being a coach and asking questions.

- Nick: I think the…you know, from looking back to specific moments when I was facilitating when I felt like I was in that facilitator role; it was when I…it was to help with the drift. Just to bring us back to either what we were talking about or the standards, specifically the science content. That's been a really big thing, a really big help for me, being able to emphasize Understanding by Design and the standards.

As evidenced above and below, you can see how Nick's facilitative role and focus on the standards plays out.

- Nick: If we can come up with some other measurement tasks that would be great. But you know again, it's a little bit…I don't want to get too far from the science standard because the science standard doesn't…it's a qualitative standard, right? And that's okay.

In this excerpt, Nick is urging his team to find a new activity related to data measurement. He does this by noting the importance of the science standard while also noting the ‘qualitative’ nature of the math standard the team is interesting in hitting. Conversations of this nature took place across all three teams. Below, Hank is slightly panicked by the wide array of standards his team has chosen to align their unit with.

- Hank: I feel like we've bitten off more than we can chew and that’s fine; but now we wanna start deciding what are our real goals for our students.

  Derek: Yeah.

  Hank: And part of that comes down to what you are all required to do, like Laura was riffing on. You know there are standards you are arguably supposed to be teaching right.

Hank dances around his concern slightly here by referencing the standards and the teachers ‘requirements’ to teach the standards. He is attempting to get the team to focus their unit on a few key standards, mainly because they currently have too many. Two last exemplars from Team EttR and Nick will add to this theme by demonstrating how concepts, not just standards allow for a coach to focus his or her team during the design process. This first question from Nick revolves around states of matter and phase changes.

- Nick: My question is what do the kids know about liquids and gases and what do you hope that they learn about liquids and gases in fifth grade?

  In this next one, he focuses his team on the concepts of gravity and friction.

- Nick: So this is the place where we wanna say…where we wanna actually get them to say that gravity is a force that pulls things towards the earth.

  Nathan: Yep.

  Nick: And friction is a force that impacts motion or something like that.

A slightly different strategy that was utilized during the curriculum design process was paraphrasing. Paraphrasing was used to help clarify thoughts and words that may have been unclear or in need of further development. Hank exemplified this strategy with several exemplars where he paraphrased his team's ideas. Below, are two exchanges that demonstrate the use of paraphrasing.

- Hank: Exactly what you're describing Evan is this idea that I'm gonna generate some data or be given some data. I need to understand it and that's going to inform the changes students make. That's really the goal of integrating the engineering processes with the scientific concepts and mathematic processes. That's huge and I'm glad you bring that up. How can we have the students making decisions based on their understanding of data 'cause that's what engineers do right?

Hank is facilitating the team through the design process here. He is getting them to think about scientific concepts and mathematical processes by literally using the ideas and phrases teachers are saying in the moment. The next extract took place roughly 10 minutes after the first, and again has Hank openly 'rephrasing' the predicament Jill had just identified the team was in.

- Jill: So what would the engineering challenge have to be for this one in order to have it…to use the…

  Hank: The science content or the gear ratios…so here, how does an engineering challenge…if I can just rephrase what you said? How does the engineering challenge draw out forces, motion, and energy transfer? In this case, how does the engineering challenge draw out gear ratios, simple machines, input, output…which one does it's job better?

The ability to have a team member who can focus a team, while always keeping in mind the standards or concepts is valuable. The aim of bringing this theme into the larger category is to exhibit the facilitative role that coaches enacted.

Coaches as teachers and experts. With the exception of Team LD and Abby, the other two coaches served the role of teachers or experts with their teams. Abby self-identified her lack of science content knowledge and her team as seen below was well aware of this.

- Evelyn: I think this would be fun as we're writing it maybe if they didn't have the same claim but if we claim that a catapult with a longer arm will and then, that's the claim and then their evidence.

  Abby: Well that's not a claim that would be their hypothesis right?

  Evelyn: No well…the claim would be, we claim that a longer arm will shoot further.

Abby: Okay.

Both Nick and Hank however served vital roles as experts with their teams. Their ability to interject and engage in teaching moments with their teams was outstanding. Below Team RF has a discussion about Hank and his role as a teacher.

- Michelle: You're a teacher to us.

  Evan: What are you doing, you're sitting right here and teaching us.

  Hank: Well I'm not…I have a lot of respect for K12 folks and that's what you guys do and here I am just a graduate student.

Hank had earlier said to the group that he was no longer a teacher, and the team quickly corrected him and indicated that he was 'teaching them'. Below, Hank responds with an answer to Jill's question about the plausibility of having students design a process, rather than a process.

- Jill: Does that qualify as an engineering design problem?
- Hank: That's what we were just talking about earlier and yes it would. It would be more in the, looking at the standards, engineering habits of mind using an engineering analysis process to solve a problem. You don't have to build something you can go through this process with bike cadence.

The team looked to Hank throughout the design process to provide answers to their content-focused questions. Hank was happy to provide answers to science and math questions.

- Michelle: Couldn't you use mean, median, and mode to tie that in with the math standards for?

Hank: That works really well when you're counting things right? Or if you're looking at ages in a group.

Derek: Data plots.

Hank: Yeah with something where it's a relationship with two variables that's a little more challenging, I have to think about that.

Hank understood that his team's understanding of appropriate and meaningful math integration may be underdeveloped. His confidence in his ability to facilitate the teachers' learning during the design process was exhibited here and was also present throughout the design process.

Nick also took on the role of teacher and expert with his group. Below are two exchanges where he provided content knowledge expertise in science and math.

- Matt: Can we use friction to turn something? Somehow there's more friction on one side than the other.

  Nick: I mean that's how boats turn right? You stick your oar in.

  Matt: I guess that's kind of like bikes turn.

Simple questions such as these were quickly answered by Nick when they came up. He was also willing to go into longer explanations when he deemed necessary.

- Nick: Cause like if you take data points and then have them calculate the mean…I mean that's good practice for calculating the mean; but as far as data analysis goes, you know I would wanna see if they can structure a conversation about it. Is the mean what we wanna do here or is the…we need to talk about the mean you know…tools to structure those conversations. And we haven't had those conversations yet and were not ready to…so it's fine. I'm sure that we can get it in there but…

The team was considering having the team calculate the mean for the distance that their cars would travel, basically just for the sake of calculating mean. Nick saw this as an opportunity to interject and provide insight into a more meaningful activity that students could take part in. Nick's background in math and his experiences with pre-service mat teachers allowed him to facilitate his team's understandings of meaningful applications of math in an integrated curriculum. Coaches not only served as experts, they also were occasionally idea generators.

Coaches as idea generators. The complex nature of STEM-integrated curriculum design warrants that ideas be presented and pursued. Every coach contributed to 'brainstorming' sessions by contributing ideas in one fashion or another. Hank was willing to divulge that the idea the team ultimately went with was one that he initiated.

- Hank: I'll admit I actually suggested the bike idea when they were saying I wish we had a more relevant context and I said something along the lines of what about designing bikes for low income families 'cause we did this plot in the PD of gear ratios. They had a 21-speed bike and one of the things we observed on this plot was that I can do the exact same gearing ratio three different ways, three different gear combinations. Is that excessive? And so I suggested we could design bikes for low income families and say maybe we need less gears, maybe that would make it cheaper, maybe that would get more people riding…just kind of threw that out there. I wasn't present the following day and that was when they just really decided to go forward.

Despite Hank's absence the day the team decided to move forward with the bike idea, the team took up the idea. Hank was aware of this, though he felt that the team would not necessarily identify him as being the initial source of the idea. Nick was also willing to give his team major ideas. The following idea mirrors the one the team eventually settled on.

- Nick: One thing that seems like a really natural fit, especially with the context is the forces change direction.

  Sammy: Yep.

  Nick: I think that could be…that could be easily built into the test so I think that it could really hit that…hover craft thing could really hit that design…it could really hit that standard well I think that the um…you know stopping starting, change in direction. You could, I think that would be good…simple like the apparatus to lift the thing I think that that could hit that standard really well too but it almost seems like two separate designs, you know it seems like, and I'm wondering if we could scaffold that some way. If you just decide to focus on one and maybe hit the other one I don't know, I don't know there's different ways to think about it but yeah I think those are my thoughts at this point. But again you know this is really early on so were just bouncing ideas…

Abby also provided potential ideas for her team to consider, though not as frequently as Hank or Nick. The context that the team eventually chose for their unit was one that Abby had suggested.

- Evelyn: It's more like Abby was talking about…how there are buried mines and bombs in Laos, and Somalia, Egypt.

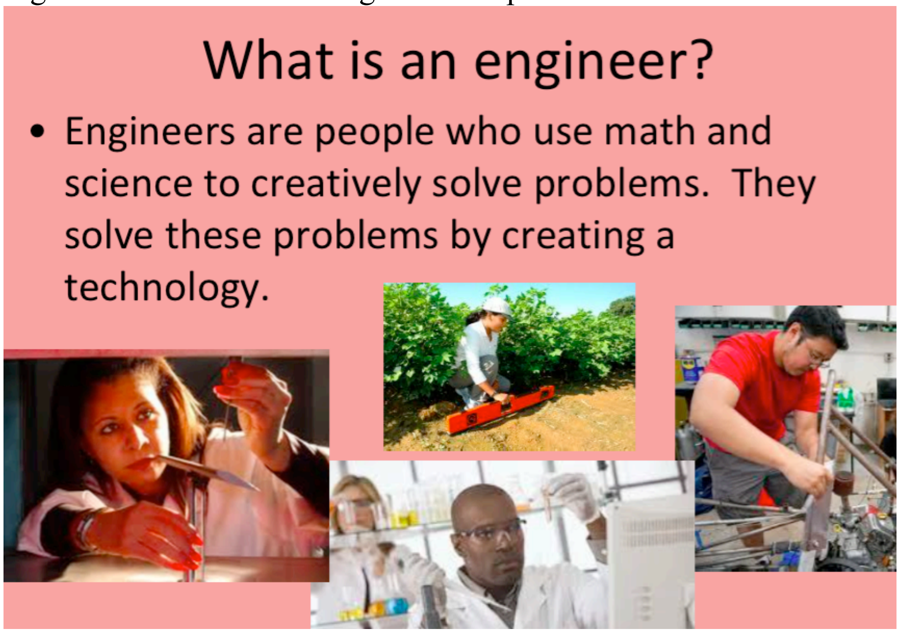
She also provided an idea related to how to start out the unit that the team took up.

- Abby: This could be like when you introduce engineering for the first time right? If you wanna identify how this thing can be improved or like what does an engineering do…and that can start a conversation about like what an engineer does; here's an example.

  Evelyn: I like that.

This idea, initially suggested by Abby, can be seen put into action in Figure 4.9 as the team created a series of slides to start off the unit asking students to first identify what 'engineers do'.

Figure 4.9: Curriculum design artifact: presentation slide that was influenced by a coach.



Nick was more open and vested in providing his team with potential ideas for their unit. The multiple options that the team was considering for their final design challenge also put Nick in a position to provide more ideas. Below, an idea related to the engineering design challenge involving a rescue vehicle can be seen.

- Nick: Another idea…it may be a little too simple, would be two separate tasks. One where it's gotta start from a stop and get going and then it can cross, and then another where you push it and then it has to stop itself.

Here, Nick put out an idea for consideration. Both he and the other coaches frequently did this. Again, below Nick can be seen putting out an idea related to the design challenge again.

- Nick: But reducing friction could be, I mean maybe part of the task is they can put down, they can build a track and they can decide whether they wanna make more track out of felt or snick wrap or you know things with different surfaces…

One last idea from Team EttR below has Nick exhibiting some excitement as he provides an idea related to the context for the team's unit.

- Matt: Friction or whatever…

  Sammy: But then the client would be hiring them for like…I'm not…

  Nick: No! Think big. It could be like a hovercraft company is building, like an actual hovercraft company.

The team was initially unsure of who would be interested in having them design and build a rescue vehicle. Nick felt that this was a part of his role and suggested an idea.

Coaches were idea generators, as evidenced above, however; they were not necessarily responsible for putting ideas into action. The act of bringing ideas to life via writing or messing with possible materials for the design challenge was primarily seen as the teachers' responsibility. Coaches could facilitate the team during idea generation, but teachers needed to take the idea to the next stage. Below are two examples of this reality from Team RF and Team LD. Evan during his individual interview stated the following.

- Evan: You might be the skeptical eye or you might be the supportive…you know depending on what the team needs at the time. People are like stuck and struggling, you might throw something in there to knock the pins down and get things rolling.

For Evan, Hank's role with the team was to get the team moving in the right direction, to provide that idea to move the team forward. Abby, during her individual interview also talks about this aspect of her coaching role. She tried to encourage her team to not 'just tell' their students something. She would get them started with an idea that she expected them to further develop.

- Abby: I would say it comes in how I guide them to…or encourage or guide them into teaching it in a meaningful way. So again away from the telling and more from like showing…here's a story or here's a video or here's some creative ways that I've learned about engineering in science teaching.

A coach's opinion matters. Coaches were in a position to guide, assist, and overall help their team. Their influence on the design process and the unit the team attempted to create was great. Their opinions were so great at times that one coach in particular felt the need to try and 'hide' his concerns when they would come up.

- Nick: There's parts that worry me and I know that…well I don't know…I don't know how well…how easily they can read me or stuff like that. But they've…so I try to hide when I'm really concerned about something but I'm sure it comes across.

Later on in his interview this tension again came up.

- Author: So do you feel like you've been portraying a certain type of confidence to them or has it been just your own personality?

  Nick: I don't know it's hard to tell…I mean I haven't been trying to act.

  Author: Yeah.

  Nick: You know I've been trying to reserve judgment as much as possible but I mean I do like the curriculum I think it's good.

Some of the examples above indicate just how influential a coach's opinion was. Below are more examples that detail just how influential they were. The purpose of identifying the importance of a coach's opinion is to suggest that perhaps a coach should be more involved with the follow through after an idea gets suggested, no matter who proposed the idea. If coaches are seen as experts and idea generators willing to make their opinions known, why shouldn't they be more involved with the development of a particular idea?

Hank and Nick both discussed their team's interest in hearing their opinions during the design process.

- Hank: That being said they really wanna keep me involved. They wanna know my opinion. That kinda further complicates this idea of the coach being this…I don't wanna say passive observer but the guy who is just asking questions.

  Author: Yeah.

  Hank: Pushing things…no they want me to be in it like they're in it and so I feel like I'm doing them a disservice if I don't.

During the design process, Hank was very loyal to his facilitative role as a coach. However, he was aware that the team at certain points wanted him to break mode, and step into a new role. For him to just sit back and ask questions, would be a 'disservice' to the teachers he was working with. He wants to 'be in it like they're in it'. Hank was aware that his opinion mattered and was not sure how influential he should be.

- Hank: I try really hard to frame it that way…like this is my opinion and I always wonder as soon as I say it am I supposed to be doing that as a coach.

Hank goes on further to describe his belief that it is acceptable to interject his personal opinion at times with the following:

- Hank: There's been various ideas what we should and shouldn't be doing as a coach…however a lot of that seems very hands off a lot of that seems like it's not supposed to be prescriptive. You're supposed to ask questions and guide their thinking which seems very ideal and awesome to me. And yet at a certain point I've felt even in this summer pilot the need to say…you know what? This is gonna cause some problems in my opinion and here's why. So for me I'm kind of balancing that role of coach as it's been presented to us…with my need to interject my professional opinion.

Nick, while not as descriptive, discussed how he encountered this reality.

- Nick: You know, sometimes they just look to me for reassurance that something is going well and I've just been trying to…or (they want to know) that this idea will…cause again you know, it's cause of that power structure right?

Nick has experiences and knowledge that his team craves. They want a leader, more so than a facilitator at key points during the design process. Nick knows he has a certain 'power' in the group and as a result the team looks to him for 'reassurance'. During Matt's individual interview, Nick's influence on the team comes out.

- Matt: No, I think it's like our whole team because I mean he (Nick) has provided quite a few good ideas. We've gone to him for help a lot everyday asking about how we could make this work, what do you think about this…and he's provided lots of background too. So I mean he's…um I think he's helped guide our unit quite a bit.

Derek, who worked with Hank, was quite animate about the role he occasionally wished Hank would fulfill.

- Derek: And as much as sometimes it'd be nice to you know…HANK…take on that lead or help with…you know make this…he doesn't. This is good though 'cause I think it helps us…we get a better buy in from the rest of us when we decide on something.

Derek knows Hank is a facilitator. The crux of the issue lies in whether or not Hank should be helping his team design the best unit possible, or should he be helping facilitate his teachers to become better designers. This came out when Hank's team was at a key point during the design process. The team was attempting to decipher what Hank was able to do or not do during the design process.

- Jill: I still think like…Hank can you participate or are you still more of a…

  Hank: Oh yeah, let me, I mean I guess I never did a good job of explaining kind of what I can do…the truth is I was joking with you earlier. I'm not an evaluator, but that is true right…I'm not. My goal is to not tell you, yep that's good, that's bad.

Hank had earlier joked about his role as an 'evaluator'. He was a facilitator. The team was trying to figure out who should be writing which lesson plans and they wanted to know what Hank's availability was. One last example from Hank and Team RF provides a bit of contradicting evidence to the influence of Hank's opinion with the team. Below, Jill was interested to know if the permission Hank previously granted to the team was legitimate. She inquired with one of the project's co-principle investigators, Angela.

- Jill: So if efficiency is the least human effort for the greatest distance then is a valid engineering design problem to say, like design modules for the bike shop, like they're our client…

  Angela: Yep.

  Jill: It is?

  Angela: Yep.

  Hank: That's what I just said.

  Derek: (laughs)

  Jill: Okay, now that we said it…

  Derek: We only trusted you….most of the time.

  Jill: We believe you, we believe you Hank. You're just…

  Angela: It's okay to believe then validate,

  Jill: Now that we got the gold star for that.

Hank had previously okayed the idea of having the team's unit involved engineering a process rather than a product. And even though Hank had previously okayed the idea, Jill wanted to make sure by checking with one of the project's principal investigators.

Summary: Coaches as facilitators. Coaches were the primary contact point for all teachers during the design process. Each coach was assigned only one team of teachers to work with and therefore spent a majority of their time over the 12 days of the PD working solely with one team. Coaches and teachers were both aware of the facilitative role coaches took on during the design process. Being a facilitator was what was asked of and carried out by the coaches in this study. However, given the type of challenge the team was facing and the reluctance of teachers to design a curriculum for a classroom other than their own, a different approach may be warranted. Facilitating teachers during the design process is justified when the teachers think of themselves as designers first, and teachers second. Facilitating teachers who think of themselves as designers second results in curriculum that is similar to the curriculum the teachers have used in the past.

Along similar lines, coaches in the study wanted to and occasionally felt the need to step into a role that was one other than a facilitator. Not only did this occur, the teachers in the study occasionally craved it. Moving into the next theme, will further develop the category by describing how teachers related to the PD model throughout the design process.

Theme 2: Professional development models. There were two major actions that can be attributed to the PD model as a whole. First; during the curriculum design process, teachers borrowed activities that they themselves participated in for their own unit. Second, a slogan of assessment was adopted by all three of the teams. This slogan provided a measuring stick that each team's unit was held up to, despite the challenging nature of the assessment.

Replicate activities from the PD. The PD activities that the teachers participated in during the PD were viewed as 'show and tell' activities that the teachers would borrow from during the design of their unit. Teachers would borrow these ideas and modify them as needed to fit in with the unit they were designing with their team. Evan described via a daily reflection why exactly teachers were likely to borrow activities from the PD with by writing, “The bike gear activity was very engaging. That was a wonderful example of a process that supported our understanding.” Teachers not only learned from these activities, they also considered how they could be applied in their own classrooms now that they had participated in a specific activity.

Similarly, Derek discussed the importance of identifying the importance of adopting the bike idea for their unit.

- Derek: Um…I think probably our unit plan…one of the major things is that…is that our unit plan is coming off of one of the lessons that we did with the physical science group.

  Author: Okay.

  Derek: So that was a big ah ha moment for us to get that.

The PD activities that Derek participated in with the physical science group were geared towards the same content standards that were available for his team to design their unit around. It therefore is not overly surprising that one of the activities they participated was adopted for their unit. Another exchange from Team RF indicates the influence that the PD had on the team.

- Hank: Like the model eliciting activity…at the end you didn't build a bat.

  Derek: Yeah you did have a process.

This again eventually became a part of the team’s unit. Towards the end of the PD, once their initial thoughts of having their students design an entire bike, fell back on the idea that teams of students could design a pamphlet of brochure that would teach someone how to ride a bike more efficiently. This strategy was directly lifted from the PD. Another exchange, again from Team RF, shows another aspect of the team's unit that was adopted for their own purposes.

- Hank: Within this engineering design challenge they talk about a client.

  Michelle: Don't you have a letter?

  Hank: Constraints which are realistic…

  Jill: A letter?

  Michelle: Yeah, write a letter and then…

Michelle in particular here has picked up the teaching strategy of using a client letter to introduce the design challenge to her students. This was previously used during one of the whole-group PD activities involving an aluminum bat that Hank mentioned earlier. This activity also resonated with Team LD. Below, the team discusses the use a worksheet to help students breakdown the client letter.

- Abby: Kind of like the model eliciting activity when they had the super easy questions.

  Rita: Yeah after you read it (the client letter).

  Abby: Yeah, they're called pre-req questions…so make that into a worksheet maybe?

One last exchange, this time related to redesign, an important aspect of the engineering design process. The team participated in an activity where they discussed their design choices with a different group. This feedback was intended to help the team consider a different design.

- Derek: You know…like we did this morning where we explained to another group and that other group had questions.

  Jill: There seemed to be value to that.

  Derek: Yeah absolutely.

  Michelle: Yeah.

Derek started off by indicating that the idea came from an activity that morning and the group latches on to including this type of student feedback in the redesign section of their unit.

These four examples, and the many others collected, indicate the main takeaways teachers took from the PD activities. Teachers borrowed entire unit ideas that they could adapt for their own purposes or they simply borrowed a strategy they felt they could do with their students during the engineering design challenge. This show and tell style of PD allowed the teachers to experience an activity that they would then consider applying in their own classroom and unit. Evelyn and Evan took notes during the PD and discussed the purpose of these notes as being ideas for the unit they were considering adopting during their individual interviews.

Theme 3: STEM-integrated slogans. Quickly evaluating a curriculum while actively discussing it with a team is not easily accomplished. To account for this difficulty, all three teams of teachers and coaches took up a similar slogan of assessment that their respective units need to strive towards. There were slight differences between the groups, but the underlying message of each slogan was nearly identical. Different PD activities that the teachers participated in instilled the slogan that all teams abided to. Matt sums the slogan up nicely below.

- Matt: That question, I think Angela or somebody asked. Can the kids complete this without knowing the science, you know? And so we've been constantly coming back to that and constantly coming back to those two science standards in particular. Really working those in a meaningful way or trying to at least…And then trying to have the kids understanding of those standards guide their decisions in the final design challenge or activities.

The teachers and coaches were concerned that students would be able to walk into the design challenges they were creating without applying any science. The teachers did not want the challenges they were creating to be completed by tinkering, or trial and error. Matt also described the importance of this in one of his daily reflections.

- Daily Teacher Reflection – Matt (Day 6): The biggest takeaway for today was the question, "Can you complete this activity without understanding the science and math concepts?" I think this is an important question because often in an engineering challenge you could complete it through trial/error without fully understanding the concepts behind the challenge.

Rita also identified a similar statement to Matt below.

- Rita: The biggest thing for me was to make sure our engineering is using science and not just finding a unit that they can do without the science. So specifically how to include it and for them to use it.

Evan and Jill, in a similar exchange indicate how prominent this slogan has been for them as they attempt to design a complex and content-focused design challenge.

- Jill: And then we all have that question embedded in our minds a thousand times…Can you do this without the science?

  Evan: Right. We're trying really hard.

Teachers actively discussed the importance of ensuring that their design challenges could not be accomplished with any science or math.

- Sammy: They need to do the science to do the engineering 'cause otherwise they'll do trial and error.
- Nathan: An engineering piece that they can build that will reinforce those learning targets.

Teachers within the study not only echoed this slogan, or a version of it, amongst themselves, they also heard similar evaluations of their ideas from other teams. Below Sammy discusses what another team of teachers told her about the design challenge they were considering.

- Sammy: The feedback we're getting when we share with other teams or other coaches, the feedback were getting is to really make sure they're using the science during the engineering that they're applying.

The entire PD was consumed by this slogan. It was a source of assessment that could easily be stated in conversation for the teachers to consider when they were discussing the final design challenge. Hank discussed the importance of including the science and math in the final design challenge below.

- Hank: The question is…is there a nice connection between these two (standards) that students will get? Or does it really seem like were doing science and then we're tacking on engineering or vice versa? So the question's up there, is there an explicit connection that students will recognize that the science I'm doing here totally fits with my engineering challenge or are they gonna see oh teamwork, problem solving, oh and then I gotta do some science here…Kind of like what we were asking yesterday with the wheel cart activity…Could you get thru this activity without having to apply any science, that would be an example of something that would be full tilt engineering and/ really not a strong connection…

  Evan: Right.

  Hank: And what she said, can the engineering challenge be completed without using the science?

This slogan persisted throughout curriculum design conversations. It was not a formal source of evaluation, but in conversation teams would discuss the need for students to complete the design challenge by 'using the science'. If students could complete the design challenge without the science, it was considered tinkering, or 'full tilt engineering' and not true integration.

Evan struggled with integration and this version of STEM. As previously discussed he had a particular vision of what STEM should be and he was challenged by the slogan in regards to the team's proposed final design challenge.

- Evan: Ultimately what were going to be asking the kids to do is take all this…all these pieces that we had them work with and mess with…and then apply it to a whole bike system of their own design…right? So the application…the demonstration of their knowledge is in how they apply…how they design their bike.

The content knowledge, specifically science, was his concern. This needs to come out during the final design. It needs to allow them to 'demonstrate their knowledge'. This is challenging. Designing a final design challenge that simultaneously required to apply scientific understandings while taking into account a variety of constraints is difficult. Again, Evan describes the perplexing nature of the task he's presumably being asked to accomplish.

- Evan: Well one of the questions that we've been asked in other things that we've been doing…Can you do this, can you do this challenge without the science? Can you do the challenge without applying the math?

  Hank: Absolutely.

  Evan: So one of the things we need to think about is what is the challenge that we're asking them to do and how can we embed math and science concepts that make it in? How can we create this so that they are forced to use some of those ideas?

The very fact that Evan feels the final design challenge needs to 'force' his students to apply scientific understanding or mathematical reasoning is at the heart of this issue. Instead of allowing Evan to contemplate a design challenge that will engage his students in a meaningful and challenging activity he is now being asked to further consider his students application of science and math to the challenge. He was not provided with any strategies to ensure that this happens nor is he provided with any troubleshooting mechanisms for figuring out if in fact a student could complete a design challenge by tinkering. Instead he is left holding up a proposed idea (having students design a bike for a specific population of riders) to a difficult to attain standard and he struggled pairing the two. Below, Evan admits his need for help with accomplishing this task.

- Evan: I need more help with seeing what the process and…messing with the bikes would be. I don't see any…I don't see getting beyond the design and that without…that’s not engineering. You're just messing and to me…and maybe that's not true.

Evan has a set vision in his mind of what engineering is supposed to look like. The slogan took hold for him and created a stopping point that he may not be able to work around. There was one admission of truth stated by Nick regarding this slogan, though this was the instance of disconfirming evidence where an individual did not hold up this slogan as a model for evaluating an engineering design challenges worth.

- Nick: Um…so you have to…I think…honestly. I like…I think its…a truth in…for anyone doing one of these, for most of em (laughs)…you probably could do it without (laughs) you know what I mean (laughs) you know, you probably could get it.

Here Nick goes against the slogan and admits that most design challenges could be completed without applying a certain scientific understanding. He struggled slightly when admitting this, but was willing to break mode when discussing the reality of feasibly requiring elementary students to have to apply science or mathematics understanding during an engineering design challenge.

The slogan that was put forward for teachers to consider while designing their final engineering design challenges was a cautionary note, not a motivator. It was an undesirable trap that you could fall into. This was reinforced by the "Make it Better" activities that teachers participated in during the PD. These activities were not presented as exemplars, but rather flawed ideas. The teachers were aware that designing an engineering unit that did not proportionally integrate science and math was not the desired result. This again, ties into the larger theme that teachers were facilitated during the curriculum design process and forewarned about what not to do. They were not asked to be innovators. They were presented with a slogan that took on an evaluative role during the design process. This hindered the design process rather than enhancing it.

Theme summary: Professional development models. The PD model as a whole had two main aspects that were taken away by the teachers during the design process. Each process lends itself to the larger conceptual category by identifying the facilitative nature of the PD. These two aspects of the PD, while less influential than each team's individual coach, impacted the team's thinking and actions during the curriculum design process. The argument is that teachers were facilitated, not inspired during the PD.

Conceptual Category 3 - Possible Avenues for Exploration

The last conceptual category includes a wealth of data sources, themes, and analysis with the primary intention being to explore possible directions for encouragement and innovation to arise from. Table 4.6 displays the category and underlying themes and sub-themes.

Table 4.6: Possible avenues for exploration.

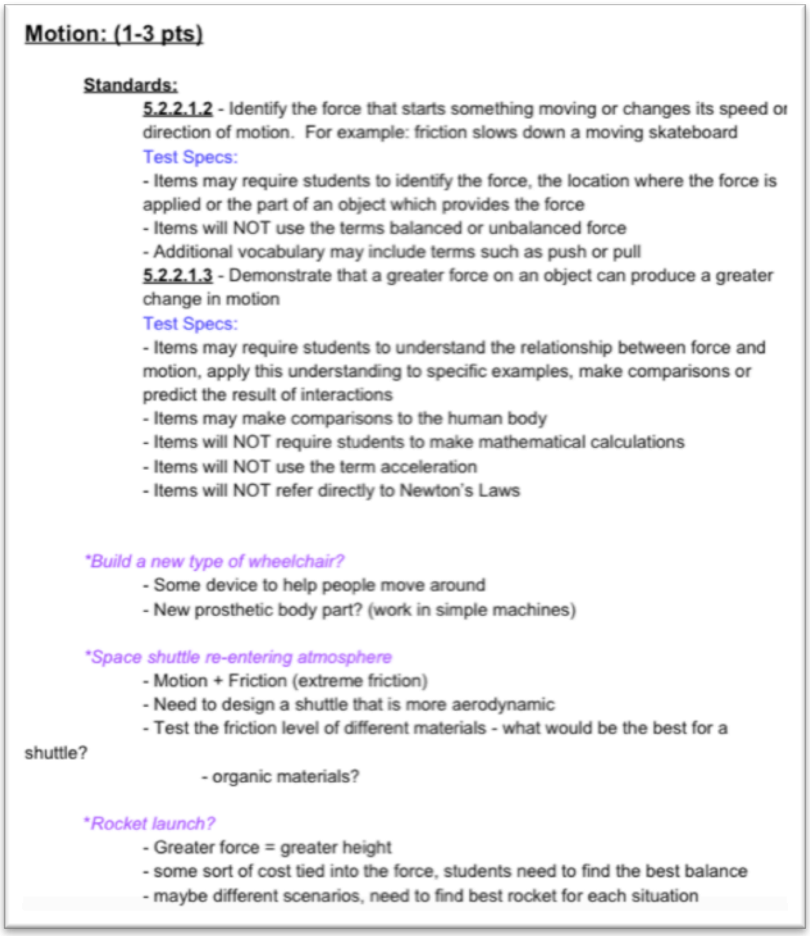
Theme	Description	Sub-Themes
Embrace Complexity and Ambiguity	Instances during the curriculum design process where problems are ill defined and the solutions to the identified problems are unknown.	Content standards integration: complexity and connections, refuse the urge to simplify, coaches play an important role why not ask them to do more?
Curriculum Design Directions	Aspects of curriculum design that emerged from the data as being potentially challenging for teachers or areas where further support could be provided.	Decision-making skills, defining the puzzle pieces, lot's of talking little writing, glossing over the details
Provide Teachers with Insights into how Teachers Use Curriculum	The realization that providing teachers with more information about how teachers interact with curriculum resources may foster a designer mindset for teachers during curriculum design.	I use curriculum different than you

The first category identified and described how teachers tend to design and make design decisions based on their past classroom experiences and their own classroom contexts. The second category demonstrated how a facilitative role fails to overcome these tendencies, as teachers remain the sole deciders of what transpires in a given curriculum and therefore continue to design within their assumed capacities and comforts. The purpose of this last category is to identify places in the design process where teams encountered difficulties. Difficult terrains were encountered when complexity came about, options where confounded by multiple variables, and the path to success was unknown. Typically, as will be revealed below, there were instances where trouble spots came about. Something different was happening. The teachers and coaches in the moment were transformed as they needed to find a solution to the problems they were facing. Their choices, as evidenced in the data, helped to identify situations or predicaments that allowed the teachers to move on or move past a challenge; with varying levels of success. These avenues allowed me to consider and contemplate what could have been done differently in a given situation. Two themes emerged from this process, each with underlying sub-themes.

Theme 1: Embrace complexity and ambiguity. The first theme in this category has been synthesized to demonstrate the myriad of complex challenges teachers must take on while designing a STEM-integrated curriculum. These challenges when not fully explored or vetted, present ambiguous and somewhat unfamiliar territory for teachers. By identifying various complexities and associated contexts the aim is to provide directions for or strategies that could be beneficial for teachers involved in curriculum design.

Content standards integration: Complexity and connections. The challenge of integrating multiple concepts or content standards in one cohesive curricular unit lies in discovering connections and patterns that are not well defined and difficult to connect. Figure 4.11 displays just how complex of a task this can initially be. The document below contains the two content standards the team wanted to align their unit with, along with several 'test specs' that further describe a variety of tasks that will 'NOT' be included on the state's annual standardized test, for example students will not have to make 'mathematical calculations' for standard 5.2.2.1.3 (see Figure 4.11). The bottom of the document contains three initial ideas, in the form of questions, which Team EttR created early on in the design process. The team's initial thoughts (e.g. a new type of wheel chair, space shuttle, and rocket launch) are beginning attempts at designing a unit that is driven by content standards that take into account certain constraints as dictated by standardized testing.

Figure 4.11: Team digital document containing standards, test specs, and possible unit ideas.



Motion: (1-3 pts)

Standards:

5.2.2.1.2 - Identify the force that starts something moving or changes its speed or direction of motion. For example: friction slows down a moving skateboard

Test Specs:

- Items may require students to identify the force, the location where the force is applied or the part of an object which provides the force
- Items will NOT use the terms balanced or unbalanced force
- Additional vocabulary may include terms such as push or pull

5.2.2.1.3 - Demonstrate that a greater force on an object can produce a greater change in motion

Test Specs:

- Items may require students to understand the relationship between force and motion, apply this understanding to specific examples, make comparisons or predict the result of interactions
- Items may make comparisons to the human body
- Items will NOT require students to make mathematical calculations
- Items will NOT use the term acceleration
- Items will NOT refer directly to Newton's Laws

*Build a new type of wheelchair?

- Some device to help people move around
- New prosthetic body part? (work in simple machines)

*Space shuttle re-entering atmosphere

- Motion + Friction (extreme friction)
- Need to design a shuttle that is more aerodynamic
- Test the friction level of different materials - what would be the best for a shuttle?
  - organic materials?

*Rocket launch?

- Greater force = greater height
- some sort of cost tied into the force, students need to find the best balance
- maybe different scenarios, need to find best rocket for each situation

This complexity of creating STEM-integrated curriculum comes out during the design process as teachers come against having to identify specific content connections for their unit across three varying disciplines: science, math, and engineering. Derek noted this reality after day 7 via his daily reflection.

- Daily Teacher Reflection – Derek (Day 5): One debate we were having was do we need to have all potential standards in line for our unit or do we start with the science and add other pieces (math, engineering) later. As of now we are going to add those in to our preliminary work.

The teachers, as Evan eludes below, were well aware of the challenge they were up against.

- Evan: (laughs) It’s kind of overwhelming to look at all the different components that you're trying to integrate; math, science and make it authentic engineering. It's a really big thing to try and figure out how to deconstruct it and looking at math…looking at the standards and trying to integrate those in. It's a big thing.

As Evan states, ‘it’s a big thing’. It can be ‘overwhelming’. However, it can be done and teachers need to embrace this complexity and strive for a solution. Teacher should be encouraged to move forward and not be bogged down by the complex nature of the task. Hank, relating to his team and specifically Evan, notes the following in conversation.

- Hank: It's hard for me Evan for sure…to be thinking about multiple things in parallel. I like to say okay, we did this done, chuck it, put it over here and move on to the next thing.

Discovering a pathway to move on during design is not clear-cut. There are no signs to check off as you pass them by. Hank and his team were constantly up against this reality as they went back and forth between their final design challenge, the proposed BA’s they were considering, and the possible science content standards they were contemplating. A below exchange with Hank and Evan related to assessment emphasizes this reality.

- Hank: I know the challenge that I'm working with now going back to the picture that you've got that engineering design process for our unit is relating…is gonna be relating the problem to the testing of the evaluation.
- Evan: Yep.

- Hank: How are we really gonna make it concrete that we are solving this problem or I've got a way of assessing how well I solved this problem in part or in full? To me that's something I'm struggling with…

It seemed as if they were moving in circles, back and forth between one aspect of the unit and another, never moving forward. Derek, who served as an interpreter for the group brought the following realization to the team.

- Derek: I'm not sure this is helpful, but I think I'm trying to absorb…I know every person is coming with different aspects of this and…

  Michelle: Yes…

  Derek: Trying to absorb and take in and…

  Hank: Yeah.

  Derek: I think we're all doing this of course you know…really absorb and find those connections between the things that were doing because I think we have a lot of solid ideas it's just getting them together.

  Hank: Yeah.

Derek's ability to navigate the space as a coach and a teacher came about because of his own personal attributes that mirrored that of a coach. Insights such as this were unique. Derek was involved in the process as a teacher, but was also very considerate of his fellow teammates. This insight adds another layer of complexity to the theme, given that each individual teacher also brought his or her own expectations into the design process. Evan also discussed this during his individual interview.

- Evan: There's no…there's no really clear…pathway that everybody should follow you know and um….so because of that we came in…we have all these different expectations and so…

He realizes there is no 'clear path' and that each teacher is attempting to navigate this path with different ideas about which direction to go. Finding an idea and a pathway to execute that idea for all members of the team was difficult.

Team EttR, which again was interested in having students design a multi-purpose vehicle for rescue missions, was constantly trying to integrate multiple standards while discussing their final design challenge. Matt, who spent a majority of his time during the curriculum design process working with the materials students would be manipulating during the design challenge had the following to say about the task.

- Matt: Both this year and last year, just the process of trying to come up with ideas for what we want the challenge to be…is always a frustrating thing. It's because we always have so many different ideas and then trying to weigh the pros and cons of each and then trying to see which ones really hit the standards and then trying to think about which ones are actually feasible in the classroom. Then once we figure out if it's feasible or not figuring out okay, I think we can do this, now how are we going to do it.

Matt neatly summarizes the major targets that must be met when moving an idea from initial thought to executable action. The team has many ideas up for consideration. They must determine how each idea fits with their content standards and must also consider how feasible an idea is in their classroom contexts. Once an idea passes these hurdles, it must be flushed out and written in a way that it can be executed in the classroom. Sammy, who was also on Team EttR described the challenging nature of this process as follows.

- <u>Sammy</u>: We just have so many different options. We're looking at what the actual test will be, what their actual challenges are gonna be… we have to decide on that to know what the prerequisites are gonna be.

For her, determining the final design challenge will allow for the team to move forward with what leads up to the unit's culminating event. Initially the team wanted to have students designing various propulsion mechanisms for a model hovercraft. As Matt discussed below, it was hard to design a challenge that students would not easily be able to accomplish.

- <u>Matt</u>: One of the things about this, is there wasn't a ton of design. But I mean there was like we did this with some other groups… you guys did something I mean…There's some design, but I mean it would have to be something that includes different choices for the kids and a design that makes the best hover craft…and they can just put the balloon on top of there and then kind of make it the best.

He is able to identify that the challenge may not have a 'ton of design' because the kids would not have 'different choices'. Here in lies the difficult aspect of the design for him and his team. Not only must he require students to apply or use their understanding a specific set of scientific concepts, he must also make the challenge open-ended enough for students to be able to make choices about their design. He must consider these possibilities when deciding which materials to give students. The variables keep rising. Each choice impacts a different variable in possibly unforeseen ways. The team moved on slightly from modifying the hovercraft and decided perhaps changing the type of vehicle would be less complicated.

- Matt: So like one would have ice in it, one would have sand in it, one would have like water stuff. So then our thought was like the hovercraft could float across the water whereas the wheeled vehicle would get stuck or whatever…A hovercraft might not be very good at sand since its so uneven but uh a wheeled vehicle hopefully would be able to get over the sand stuff like that. So that was our first thought, but then um…we we're kind of getting stuck on you know the standard is forces change motion and really what we we're looking at right now is just a force pushing objects and just making it go.

This idea unfortunately affected the standard the team was hoping to align the design challenge and unit with. This reveals the complex nature of content integration during the final design challenge. In the end, Matt declared to the team that perhaps the students will be able to determine what propulsion mechanism to use in the final design challenge and it would not need to be pre-determined by the teacher.

- Matt: I'm thinking we might need to move away from the hovercraft idea just a little bit and get more of…like you said just kind of like a multi-purpose vehicle where it has a clear force that's pushing it. So maybe they want to stick a balloon on there to push the vehicle or something and maybe they want to have a propeller on there…maybe they're smarter than we are and they can think of a much better way to propel it too…cause then different groups can have different forces that start it and then different forces that stop it and that could kind of get at the standard more you know?

Teachers were aware of the daunting task of designing an innovative and complex engineering design challenge for the unit. A commonly used strategy put into place to get around this involved limiting the number of possible science concepts or math concepts that were included in the unit. This was a strategy many of the teachers picked up for their previous experience working on the project. Evelyn described how this influenced their thinking this year below.

- <u>Evelyn</u>: It's that overthinking it part, but again from our experience last year of having a real long unit to going down I think were being way more intentional about what we put in this year.

Evelyn and Rita were very 'intentional' about not having too many content standards in their unit, ultimately only using a portion of standard involving simple machines and forces. This strategy allowed the team to limit the amount of variables and possible connections that would arise during the final design challenge. This was a common strategy. Teachers were willing to take the complexity out of a proposed idea if it allowed them to move forward. Matt, in discussing the base vehicles his team could possibly use during the design challenge stated the following.

- <u>Matt</u>: I just think we need to think…to consider how many variables we're changing so maybe we can have like the same shape, different materials, or different shape, same materials or whatever. You just need to think about how many variables we're changing for each one so you know we don't necessarily have to teach that to the kids, we can just say we only want to change one thing at a time so here, we're changing materials, here we're changing shapes.

For Matt and his team, his elementary students could not just be given a set of materials and be asked to be engineers. The number of variables needed to be controlled. The design challenge needed to be simplified to ensure students could participate in it. Later on he mentioned a possible reason for wanting the design challenge to be less complicated.

- Matt: It might make sense to have like…um …maybe like one or two options for just the…like I don't want to give them too many choices for the car bases because the difference there would be more wheels versus treads. So maybe just a couple different ones to choose from not to overwhelm them (students).

There are many aspects of the design challenge Matt and his team needed to figure out. Limiting the options students have at to consider keeps thing less complicated for them, but also himself and the team which eventually need to write up the lesson plans that detail how the design challenge is to be implemented.

Refuse the urge to simplify. The urge or impulse to reduce the complexity of the design challenge or unit as a whole was an action taken up by all three teams at varying points in the design process. The complex nature of the task, as described above, presented multiple opportunities for every design team to consider simplification as a viable strategy to employ during curriculum design. To see more precisely how Team EttR progressed towards simplification on a key aspect of their unit and final design challenge, a look at a series of conversations related to data measurement. Team EttR was hoping to find a way to meaningfully integrate a data measurement task into their final design challenge. Recall that they were interested in having students explore the concepts of force, motion, and possibly friction while designing a model rescue vehicle. To begin a few excerpts that set up the underlying assumptions the team was dealing with while designing the unit. Sammy, who was new to the project begins by stating the impact that last year's experience had on Nathan and Matt.

- Sammy: The challenge was…Nathan and Matt had some experience last year that it was just kind of blown out of proportion as far as like time it sounded like mostly. But just you don't want to have it be over complicated.

This comes up in conversation with the team in relation to the materials dilemma the team is struggling with.

- Sammy: It doesn't take the reality away, but it would be nice if there were just simple materials you can use I think. It would keep the focus on the force.

Sammy mentions the content here. For her, and presumably the team, the science concepts need to remain the focal point of the unit and final design challenge. The more complex the materials, the less likely students will be able to apply their understanding of the scientific concepts the unit is geared towards. Matt also mentions the content below with the team, as he begins to realize that the challenge they are considering has a fairly 'simplistic' connection to the standard *forces change motion*.

- Matt: Cause I mean…I'm just trying to think of different ways to incorporate different forces to change the motion cause right now it just seems a little bit simplistic as far as like connection to the standards you know.

To get a look at the specific conversations the team had as they contemplated various data measurement tasks is an exchange between Nick and Matt. The conversation began by asking the question, how will we measure force?

> Matt: One…is kind of sticking with balloons, rubber bands and…so naturally measure how many breaths go into the balloon or a bike pump was an idea. Or how many twists of a rubber band or something that they can record cause the standard itself doesn't have numbers or math involved it's just bigger force is a bigger change.
>
> Nick: Qualitative.
>
> Matt: So we need something to help them see and measure without getting bogged down by formulas and all that stuff.

Matt is concerned that his students will get 'bogged down' by a more complex data measurement task for the cars they design. Therefore, he suggests a qualitative, albeit subjective solution to solve the problem. Given that the team was interested in aligning the unit with a qualitative math standard this was plausible. The important aspect of this exchange as it relates to the overall theme and premise is the tendency of teachers to move towards simplification when designing a unit and final design challenge.

The team's discussions progressed as they attempted to figure out how to have students qualitatively measure how friction impacted the rescue vehicles that they were designing.

- Nathan: Yeah, kind of like…you'll have like a checklist that's on a scale of one to three…how effective was your vehicle to cross ice, you know, simple "one" for that check off…yep.

  Matt: You get 20 points for getting over each terrain with a bonus for time…maybe the kids could up with a way to evaluate what's successful or not.

Nathan described a simplified checklist that students can complete when running their vehicles over varying terrains (e.g. sand, water, etc.). Matt followed by suggesting a 'points' system for students to analyze how successful their vehicles were at traversing the varying terrains. As the team moved their conversations along as a result of testing and playing with the vehicles, they decided that a wheeled vehicle, rather than treads, would be more plausible. The below exchange has Matt and Sammy discussing different vehicle options and methods of measuring the impact of force on their vehicle.

- Matt: And we might have to give up on treads and we could just have like wheels or a wheeled vehicle or a hover craft and then maybe the kids can figure out ways to get the wheeled vehicle to float or something I don't know (laugh).

  Sammy: And the…

  Matt: I'm sure they're creative…just trying to think of the forces that could cause motion or whatever. And then they can get a certain amount of points for each test or whatever I don't know.

The team was very perplexed with how to qualitatively measure how the type of force exerted on a vehicle would impact its motion. Matt below describes one last possible solution to their problem.

- Matt: I think they can just say the car went slow when we did less turns. The car went fast when we did more turns I think, just whatever…If we had a challenge that they measure the distance it could have like one little column where it's like describe how fast or slow the car moved, I don't know on a scale of one to ten.

  Nick: Right, right and that's another place where a track you know it could be the test could be a specific distance and they could have to cross that distance in a short amount of time a medium or long amount of time.

  Sammy: Okay.

  Nick: I don't know that's one way to do it.

The team shies away from measuring speed or velocity, a natural solution given their interest in measuring time taken to cross a certain distance. In this instance, their interest in keeping the standard at a specific grade, limited their ability to create a more meaningful and challenging task for students to engage in.

The purpose of this discussion is not to point out the "mistake" that the team made here. It was not a mistake. It was a choice and one that moved towards simplifying the challenge. The group's interest in creating a grade-level appropriate design challenge forced them into a corner, and they needed to search for a solution. Had they been able or encouraged to scaffold their students into quantitatively measuring the vehicle's motion perhaps they would have been able to focus their efforts on designing a task their students could complete in spite of the task being above grade level.

A related, but different conversation about a proposed idea involving rockets adds more depth to the limiting nature content standards can have during the design process. Below, Nathan has been tasked with developing an idea related to rockets and he has proposed a possible data measurement task that could accompany the design challenge.

> <u>Nathan</u>: Because you can also do the graphs and you know…I don't know if that is something that it can be tracked on trajectory, if we were able to video it and be able to figure out what is the trajectory. What's the speed of it, I don't know if you could do that.
>
> <u>Nick</u>: That's…oh…you could do that definitely I think. I think it would quickly get beyond what's necessary for the standards.
>
> <u>Nathan</u>: You could time it though.
>
> <u>Nick</u>: Yeah.

The idea and measurement task is challenging, but plausible. Nick quickly disregards the idea by stating it is ‘beyond what’s necessary for the standards’ which may be true. However, the immediate response and disapproval of the idea indicates how quickly complexity is placed aside during the design process. A series of exchanges from Team LD will further described how a team gravitates towards simplification during the design process.

Rita and Evelyn decided to simplify many aspects of their unit, from initial idea to the measurement task students would take part in during the final design challenge. The team had initially thought of having students design and build a catapult, given their interest in a content standard involving simple machines.

- Evelyn: We had started thinking about all the simple machines, and then we started thinking about…let's just do levers and pulleys or let's just do this catapult. Then we we're even simpler with just this…you know launching arm. So I think that trying to take a very large standard and pull it into one piece has been stuff that we have been grappling with. I mean we kind of had our idea from the beginning it's just been…

The team wanted to have students designing a lever or launching arm that could be used to accurately hit a target a given distance away. The team, as a result of a PD activity, eventually discovered that they needed to have a way to measure force. This came about because they needed to have the object that was launched hit the target with a certain amount of force to detonate a landmine.

- Evelyn: I guess were just kind of thinking about like…is force something we need to measure?

  Rita: Or can they just identify the…demonstrate that if I go harder…

  Evelyn: Is there a way to not quantify it and still say I'm increasing the force without doing the…

  Hank: Yeah cause the standard there is to demonstrate that a greater force can produce a greater change.

The team was reluctant to change their initial data measurement task. They wanted students to measure the distance the object traveled in relation to the target they were aiming at. Hank was called in to assist the team with this challenge and reiterated the nature of the standard the team was interested in. The team eventually determined that that particular standard was not going to be their focus and instead decided to focus on how simple machines change input and output, a much less complex task.

- Rita: Like our standards we're not even focusing on force we're just simply giving examples of how simple machines change input and output force. And we don't need to know how much force is.

  Evelyn: It doesn't have to be a measurable force they just have to know this force is greater than this force…so how do we prove that?

  Rita: Distance traveled?

  Evelyn: And the flatness of like the launch part right? So if we launch some play dough with a ruler versus a meter stick it should be distance traveled and how flat the ball gets…

The team determined that instead of having students calculate force by initially measuring the force exerted on the launching arm using a spring scale, they would measure 'distance traveled' and the 'flatness' of the play dough ball being launched. The team in conversation decided that students would not be aware that a certain amount of force needed to be applied to activate a landmine and it was therefore acceptable to not bring up this aspect of the context. Mary, who had earlier dropped in to help the group and who works with Evelyn and Rita during the school year, suggested that the team at least introduce students to the possibility that force could be measured in this particular task.

- <u>Mary</u>: And if you wanted to elude that there are ways to measure the force you could expose them to tools that could measure force but whether you need to at this point…cause they will later in their school life.

  <u>Evelyn</u>: I think it's like conceptual.

  <u>Rita</u>: Were getting too complicated with this idea, it was a good idea but…

  <u>Evelyn</u>: Yeah.

The team quickly disregarded this suggestion as being 'too complicated' and chooses not to include it in their unit. The benefits of at least introducing students to this method of measurement were not considered and instead put aside to reduce complexity.

The team also simplified how students would be collecting, analyzing, and displaying the proposed data they would be working with during the unit.

- <u>Rita</u>: We're going to give them a data table that they have to fill in with the type of…

  <u>Evelyn</u>: So then they're just copying it from…

  <u>Rita</u>: It will be the beginning of the year so they have to do input and output values and then what do they do with that one.

The data measurement task was simplified in this exchange. It was pre-decided that students would be just starting off the year and would therefore need to be given a data table to fill in. To display the data each team would collect and analyze the following exchange depicts the thought processes of Rita and Evelyn.

- <u>Rita</u>: And the posters would be really basic…just like your data table, a graph, your overarching conclusion…

Evelyn: Yeah like…

Rita: Create a small rubric for the…so each group knows exactly what it should look like or like what should be on their poster.

Evelyn: Then share it out…

Rita: I think less is more on the posters cause if you add too much then…and we don't have time for that cause it's too much time.

In regards to integration, the unit hinges on how vital the collected data is to students' thinking during design and redesign. Here, the team decides that students will be given a 'rubric' with 'basic' tables and graphs that have an 'overarching conclusion' (i.e. my design is the best because…). The team was also interested in having aspects of argumentation in their unit, though they were unsure precisely how this would transpire.

- Evelyn: Is it like justifying?

  Rita: It's like you make your claim, you support it with evidence, and you go farther explaining like why it…what does it mean…I don't know this is confusing me.

  Evelyn: I don't know. I'll put it like that.

  Rita: Well I just think you say M.A.G here's your problem, we built this, it's so good, this is the reason why it's good…maybe explanation why they should choose yours.

Rita described how her simplified vision of what students will 'justify' to their client 'M.A.G.' during the final presentation of their designed launching arm. Both Rita and

Evelyn indicated their lack of confidence regarding this aspect of their unit, and therefore settle on a simplified task for students to complete during the unit's final lesson.

There were occasional examples of teachers considering a more complex approach to a unit. Matt, who was influenced by Nick during the PD, hypothetically considered more complicated data analysis tasks. The below exchange between Derek and Nick starts the process.

- Matt: I wonder if we could also try to include, some sort of analysis…like the benefits of different types of propulsion or something.

  Nick: That could be like a big part of the design challenge.

  Matt: Try to work that into like a data analysis (task)…if they calculate the range possible for the propeller versus the range possible for the balloon versus the range for the wind up thing. Nathan was working on something along those lines.

This conversation was early on in the design process, and indicated that ideas can initially start off being more complex. Matt again, noted this during his individual interview.

- Matt: Yeah, like today actually we were focusing on some of the math standards…how we can not only just collect and like graph the data, but also to analyze it in a meaningful way.

Here and below, Matt is beginning to more clearly articulate how a data analysis task should be integrated into a STEM unit. He realizes that it is typical for students to just 'collect' and 'graph' data. He is interested in moving to a more 'meaningful' task where students discuss the 'importance' of the data they collected and the 'meaning' of it.

- Matt: So I mean there's like the basic ones like that, but then how to take that to the next level where they have to analyze…okay, what does this mean, why is this important?

Teachers did consider more complex and more challenging tasks; however, these were not pursued as viable options teams moved deeper into the design process.

***Coaches play an important role. Why not ask them to do more*?** In the above examples, Matt was influenced by his coach. This next sub-theme describes how influential a coach can be during the design process and propose that perhaps their influence should be leveraged more prominently with teachers during the design process. Hank starts off below with a standard utterance typical of his role during the design process.

- Hank: So obviously there's a big gap between the problem and the background you're presenting with the things we want them to be doing. So Evan's problem, it's awfully hard to think about this without getting there first and I agree but we're drafting out maybe some ideas here so we want them to be able to work with gear ratios, distance, maybe a bit of both?

Hank paraphrased Evan's concern nicely and moved on to discussing a possible strategy the team can pursue to solve the problem. He did not presumably have or reveal a solution, instead he indicated a potential solution to explore. During Nick's individual interview, he described his role as being similar to the one Hank demonstrated above.

- Nick: I think they value just my role…the fact that I'm there when we're not moving forward. I can be the person to be like, we need to move forward or we need to do something…I think that they value that. Although I haven't had to do that too much cause they're pretty self-directed.

Nick's responsibilities are to keep the team progressing in the right direction. Here again is Hank, attempting to do just this with his team.

- Hank: Well maybe let's talk about the data. That's maybe a bridge between identifying the content and defining the activity. What kind of data do you wanna see your students collecting? How do you wanna see them manipulating data like picture that in your mind, in your classroom. What do you wanna see them doing? Maybe that's a halfway point where we can start? When you sit back and say alright, we designed a killer lesson. What are they doing?

The team was struggling with a next step. Hank suggests that perhaps a discussion about the data may help with moving the team forward. He again provides no answers as this is not his role. There were certain things coach could and would do during the design process as Hank declared below.

- Hank: Actually putting pen to paper or going to the library or getting these books or calling these people…those are things that I believe as a coach it's not necessarily my role or something at least I'd like them to attempt first before I interject.

Should Hank or Nick be more involved in determining solutions to problems, rather than bringing up possible strategies or discussions that could alleviate an identified problem? This is hard to say. It's possible that had their role been different, they would have engaged with their team differently. They may have decided that they had a past experience or understanding that the team could pursue. Abby's interview response adds to this below.

- Abby: So…I give ideas but at the end of the day it's their unit, they can do whatever they want.

Derek indicated this possibility during his individual interview.

- Derek: We talked about the leadership versus coaching role before and I think that the coaching role is really huge in letting us teachers really kind of fight through some of the stuff rather than kind of jump in and you know…you guys have done more research and all that. You have…you know, you've been doing some of this stuff on your…you let us fight with it still, which is difficult. It's like HANK HELP US OUT (knocks over recorder while moving his arms) HANK HELP US ALREADY! But at the same time we need to go thru it we need to do it.

Derek clearly understands that there is a benefit to allowing himself and his team space to struggle during the design process; however, he then goes on to explain how frustrating it can be at times when Hank's involvement in the design process is constrained by his role. An exchange with Derek and Hank below exemplifies exactly how this plays out during design conversations.

- Derek: Greater force gets your pedals moving faster which gives you greater output of distance I'm having a hard time…how do we talk about force I think we can…

  Jill: He had a cool…

  Derek: We can't really do a measurable force with pedaling or can we?

Hank: Actually I was thinking about this, I wasn't going to say anything.

Derek: Okay.

Hank: But I mean we can hook up the force sensor between the foot and the pedal and we can graph how much force you're exerting on every pedal stroke. We're not going to change the gears really…high gear tons of force you could argue…spring scale but it would get a little tricky.

The team was looking for a strategy to measure force exerted on bike pedals during a measurement task. Hank had a thought that he initially felt should be concealed from the team. He then decides he will reveal his idea to the team in spite of his initial intuition. This exchange exemplifies precisely how a coach's role can be limited during design conversations. The team was up against a wall and needed to think about and find a solution. Instead of willingly jumping in with a solution for the team to consider, Hank contemplates this. Should I jump in here, or is there a value in letting the team troubleshoot the problem themselves?

Given the complex nature of STEM-integrated curriculum design and the previous experiences coaches can potentially bring into the design space, it's plausible for a coach to move into a different role and fully engage with his or her team of teachers without holding back at specific times during the design process. During Hank's individual interview he explicitly stated that his connection to the curriculum varied from the teachers who would actually have to teach it in their classrooms.

- Hank: I'm not on the line in a certain sense like you are as a teacher so I try and be very explicit about that.

All coaches in the study had previous experience working with teachers during the design process as well as experience designing their own integrated curriculum. However, as Nick indicates below, it may not be enough to fully and confidently lead a team of teachers through the maze of curriculum design without participating in the struggle with them, as opposed to facilitating them along during the journey.

- Nick: So it's not like I've already processed what the essential elements…I mean I've processed what the essential elements are but I haven't processed them well enough to be able to abstract those ideas, to see them beyond individual units.

Nick, and I would argue all coaches in the study, were learning how to navigate this new experience. He has processed the 'essential elements' but he has not 'abstracted' them to a point where he can guide others through the process. He could not necessarily see the forest from the trees. Given more experience as a curriculum developer or a coach working with a team of teachers espousing to be designers will undoubtedly help him further 'abstract' these ideas; but he's not there yet. Given this, it's possible to suggest that he help the team design the best unit possible as a rather than a coach facilitating teachers during the design process.

Two of the three coaches in the study exhibited tensions characteristic of this phenomenon. There was an intuitive "pull" that occasionally drove each coach to break mode and step into the design space as a designer, rather than a coach facilitating teachers to design the best unit possible.

Theme summary: Embrace complexity and ambiguity. The data from this section drives the notion that teachers need encouragement to embrace complexity and ambiguity during the design process. It has suggests that coaches take on the more participatory role of a designer, comparable to the teachers in the study given their past experiences and influence on their respective teams. All coaches were influential during the design process; however, their ideas were not always contributed at key points in the design process when they were taking on their prototypical facilitative role. The next theme in the category will further explore a variety of directions that could be pursued that would benefit teachers and coaches during the design process. Each sub-theme will illuminate a challenging aspect of the design process or typical behavior exhibited by teachers during the design process. In identifying these exemplars for the data, it is my intention to aid coaches facilitating teachers during the design process to better be able to identify typical areas of concern that arise during the design process.

Theme 2: Curriculum design directions. Team-based curriculum design has many challenging aspects. Teams must be able to make decision, they must actually write a draft curricular unit, and they need to address problems when they arise and not put off tasks to a later point in time. The placement of this theme within the category *Possible Avenues for Explorations* is to precisely identify troublesome areas that manifest themselves during team-based curriculum design. In grounding the theme in the exchanges typical of teachers and coaches entrenched in the design process, it is my intention to move forward the discussion about what coaches can specifically do during the design process to foster and develop a team of teacher's design skills.

Decision-making skills. The ability to make a decision when working amongst a group of peers is not easily accomplished. When there is no predetermined method or strategy in place to guide teachers in an effective and efficient manner to make decisions as a team, a range of strategies will be employed. The following sub-theme will outline and describe how two of the three teams in the study attempted to make decisions as a team.

It was commonplace for teachers and coaches to identify spots during the design process where decisions needed to be made. Matt and Evan, on three separate occasions describe this.

- Matt: Okay, so there are some options out there, we just gotta try to figure out what's good.
- Daily Teacher Reflection – Matt (Day 6): We are still having a difficult time narrowing our ideas for our unit.
- Evan: We seem to be at that stage where we're at a fork in the road with a number of things: context, the design challenge, kind of starting to narrow down what our focus should be.

In instances like this, it was easy for teachers to identify that they were at a 'fork in the road'. What was more challenging was moving forward with a decision.

- Jill: I'm not ready to say what the engineering design challenge is 'cause I'm hoping that one of you guys comes up with it.

  Derek: I think this is a hard decision to make right now with this.

Jill's group was trying to come up with a plausible final design challenge in which students would modify an existing aspect of a bike. Which aspect and for what purpose were not as easily determined. Derek during his individual interview towards the end of the PD described the team's inability to make decisions.

- Derek: I mean once we started talking about…I think either one. I think once we started talking about it, I think we had a ton of potential variables put down for both. We still need a…you know, we need to put together like context of what we wanna engineer for a design. So neither one is really that far along I don't think.

The team according to Derek felt that each possible idea they were considering had many 'potential variables'. Given that the team had yet to come to a decision point regarding their idea for the bike unit, neither idea was 'really that far along'. In addition to identifying the challenging nature of making decisions as a team, this response also provides clues at just how big of an impact not being able to make decision has on a unit's development. In not being able to make decisions, the team could not develop the next aspect of the unit. Hank, who worked with Derek, identified this challenge in the below exchange.

- Hank: Other challenges? I feel like we we're really hitting the wall on a lot of things.

  Derek: Yeah.

  Hank: Which is good, we're getting to that point where…with some of the things we are struggling with.

Here Hank identifies these points as being 'good'. It was decision time and the group needed to do so as a team, given Hank's role on the team as a facilitator and not a leader.

Teachers from both Team EttR and Team RF employed strategies to aid them in the decision making process. Derek volunteered to take notes during team conversations in hope that this would help the team identify questions they were trying to answer.

- Derek: We've mapped some of it…and so a lot of, I've done a lot of note taking because we've got so many questions were trying to answer.

Jill and Derek, both of Team RF, tried to come up with a strategy to work together as a team specifically hoping it would help the team come to decision points quicker.

- Jill: With everybody together it takes a lot longer, it's harder to make decisions but you get something richer in the end so…

  Derek: I mean what if we combined the two strategies and like took a little time to break down one lesson as a group…one person is taking notes on it, on our conversation, bullet pointing it. Then we break up and do the writing that way.

Team RF had many detailed conversations about possible ideas that could be developed for the unit, but could never settle on an idea that the team could move forward with for a variety of reasons. Nick, who worked with Team EttR identified the importance of coming to team-based decision points.

- Nick: I mean eventually before we start merely hammering out the details we wanna make sure we're happy with the idea. The good thing is if we start hammering out the details and get stuck, we have ideas to fall back on. So I think if we left today having gone thru three things good and bad about them and then slept on it, maybe tomorrow we'd be in a good place to make a decision.

Recall that Team EttR actively developed three different ideas prior to deciding which idea to develop further. The team decided to make a "pros and cons" list for each potential idea (see Figure 4.12).

Figure 4.12: Curriculum design artifact, pro and con list for two curriculum ideas.

Rescue Hovercraft - Gov. is hiring you to build an all-terrain rescue vehicle. This vehicle will have to make a through a designated route made up of different terrains with different amounts of friction.

+ Brings in background knowledge of air

+ Analyzing different types of maps

+ Brings in models

+ Students could be an expert in different types of terrain

+ Hovering over different surfaces

+ Context has a lot of potential

- Building material/time intensive models

- Data Analysis?

Water Bottle Rockets

+ Fun/engaging

+ Could include many concepts/standards

+ Graphing/Data Analysis of the distance of the rockets

- Context?

- Engineering piece?

This strategy was put in place prior to having the team 'hammer out the details' of the unit. The strategy did create some ownership issues, as Nick described below.

- Nick: Yeah, there was some ownership issues and it wasn't that bad…but what happened was when we started picking apart the idea that we were leaning towards…

  Author: Yeah.

  Nick: The person whose idea it was started getting a little bit defensive of it…not, not defensive of it but um…it felt like it was sort of a personal thing that she had to defend that curriculum (idea).

Each teacher developed a specific idea, a reasonable strategy to help the team explore a variety of options for their unit. However, it unintentionally left one teacher feeling 'defensive'. The team was only interested in providing constructive criticism of the idea. Ironically, the idea the team did settle on was the one Nick was describing.

Team RF struggled with making decisions about the unit's context and final design challenge. At one point during the final days of the PD, the team announced that the time to bring up ideas for exploration was over and that it was decision-making time. This moratorium on ideas is exhibited below.

- Evan: Is that another piece that were gonna have then…is that? Weren't we going to try and stop doing that (laugh)…

Again, Evan brings up the need to stop generating ideas below.

- Evan: I feel like were off on a tangent here…this isn't where were going I don't think, this is just an idea that we put aside right?

  Jill: So should we not…

  Evan: I don't think…

The team's inability to stop generating ideas in need of making decisions was also discussed by Hank, the team's coach.

- Hank: I can tell you what happened is members of the group got freaked out that we were just generating, generating, generating. And they said you know what? How about for a goal for today we say we're gonna tack this, this, this and that down and then I went right up to the poster and wrote. Alright keep talking you know so.

The following exchange between Evan and Jill came about later on when Jill attempted to essentially plow through a variety of stopping points that the team kept coming to.

- Evan: During the design process we're going to have them look at focused areas.

  Jill: That's what I was thinking.

  Evan: Okay, alright.

  Jill: We can change this…and the question, and order…I'm just trying to lay it out so we have an idea.

  Evan: Yep that's good. We've been stuck, we need to keep this going.

  Jill: I'm gonna keep going until somebody knocks me down (laugh).

Here Evan and Jill have decided that any interjections or ideas about what they could include in the unit are done. The team needs to keep 'going' and not get 'stuck'.

The team eventually decided that in order to make a decision, it needed to be made by someone else. Recall that the team was hoping to partner with a non-profit bike shop with the aims of having the bike shop fabricate student-designed bikes. The team had two separate meetings with leaders from the bike shop in which they inquired about the direction their unit should go.

- Jill: These are the limits we need you (bike shop employee) to set…that you can define or not.

  Evan: We have these blank pages because…

  Derek: (laugh)

  Jill: (laugh)

  Evan: Because until we can define what it is that you need us to do, or you can come up with an idea or mythical challenge that they can do…something. We can't do this piece yet.

Because the team could not move forward and make a decision about their final design challenge, they had 'blank pages' that need to be filled in. The inability to make a decision, or better said, the reliance on someone outside the group to make a decision for them, inhibited the team's ability to actually draft an initial version of the unit. It was unfortunate that the team failed to make any concrete decisions during the PD because their unit was filled with potential, both in regards to content and content integration.

During the last day of the PD, Team RF chose to again meet with the leaders of the bike shop. During the conversation, Evan again asked the two individuals to help the team make a decision about which direction to go.

- Evan: So you are acting as our client, one of the things we need from you is what do you need the kids to think about doing for you? And one of the engineering pieces of it is innovating off of another idea or expanding another idea. But for this, we need to solve an engineering design problem, so what is it? Who's the population in mind or a certain kind of bike? I don't want to use the word invention, cause that's…

Ultimately, one of the mechanics that worked at the bike shop casually mentioned three aspects of the bike that he felt would be beneficial to make modifications to. Unfortunately, the possibility to actually have the bike shop fabricate student-designed bikes was not possible due to the type of outreach efforts the bike shop typically engaged in that did not include creating custom-designed bikes.

At times, the teachers seemed to hope for a magical insight to appear.

- <u>Jill</u>: There has to be a way…where suddenly somebody's going to go okay, I see what the design challenge is…do you know what I mean? I'm waiting for that.

Others felt that if they continued to 'brainstorm' and think about what they were trying to accomplish, a decision would become clear.

- <u>Derek</u>: We're gonna…keep breaking this apart, keep thinking, brainstorming until a certain time…and then we're gonna turn it into decision time and we're gonna make it to come to a consensus together.

Derek was well aware of his team's inability to make decisions and come to 'consensus'. In addition to bringing up statements such as this during team conversations, he also had the following to say during his individual interview.

- <u>Derek</u>: Very true you know, but you always want to have that right decision and that best decision but sometimes it's just a decision you know and either way there could be different problems but they're going to have equal value most likely in a lot of cases. So you know, I think that's one of the trickiest parts about working with people.

Derek and his team wanted to have that ‘best decision’. Whether or not there truly is a ‘right decision’ that should be made is arguable. Derek spent considerable time contemplating which idea the team should move forward with. After an encounter with him I had during the PD I noted the following in my field notes.

- Researcher Field Notes (Day 8): I touched base with Derek this morning, intending to find out which day he will be coming in July. However, I ended up hearing about his inner dilemma last night. He awoke at 1:30 in the morning and went through the two potential ideas his team was considering: bikes or roller coasters. He spent about 90 minutes working on his laptop; considering the potential outcomes of each. He alluded to the scorecard his team had created the other day. The team is very much in flux with these two ideas.

The day before via his daily reflection, Derek noted that his team needed to, “DECIDE! I really want to pick a unit and go with it. I'm going to think on our context for tonight for us to run with”. He later went on to write, “If anyone has a coin, we may need to flip it tomorrow”. Derek may have wanted Hank, his team’s coach to interject and help the team make a decision, but this was not going to happen. The below declaration from Hank at a key decision point exemplifies this reality.

- Hank: Obviously bikes are fun, but seriously some of these things are more important and that might help with the decision. In fact I think I’m glad…I'm taking myself out of it here so I'm gonna play Switzerland on this one.

- Derek: Mr. Neutral.

The point here is that the team struggled just making decisions working as a team. When asked later on in the interview about one of the strategies he would hope teams would have in the future, he noted.

- Derek: Maybe decision making power. Maybe we need to come up with a method for some decision making at least by early tomorrow afternoon.

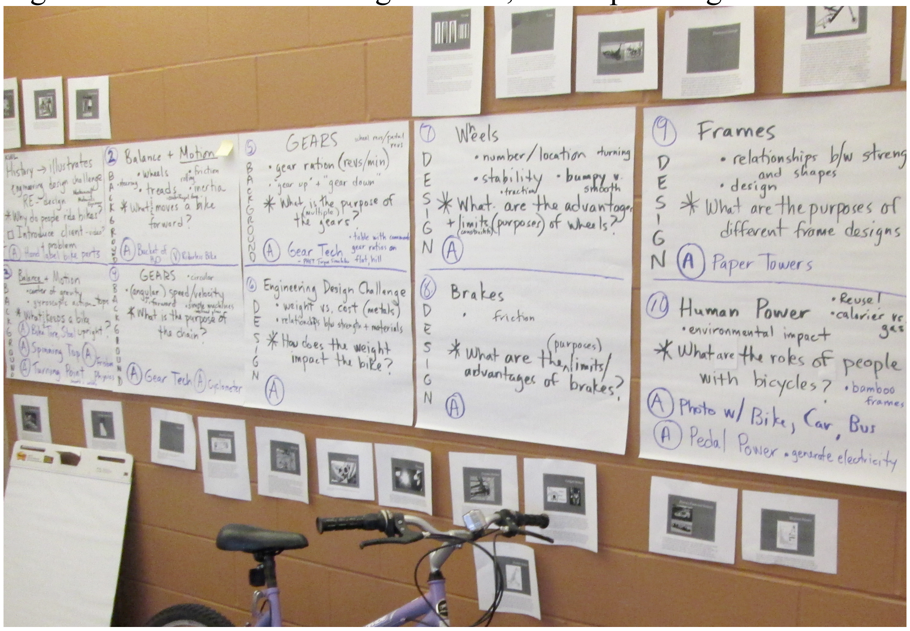
Being able to have 'decision making power' as Derek describes is a skill that emerged as being significantly lacking amongst two of the teams. The unique set up of Team LD allowed for them to more easily navigate this aspect of curriculum design due to the size of their group, their previous relationship together, and their overall unit idea. Being able to make team-based decisions is helpful to establishing an overarching vision. It is not the only aspect of the design process that must be in place to allow a team to move forward.

Defining the puzzle pieces. The 'puzzle pieces' that will be revealed and discussed under this theme emerged as an in vivo code from Team RF.

- Jill: Just taking it…what can be an unwieldy, quite complex process…and just trying to get the puzzle pieces out on the table so we can fit them together.

Jill does a nice job of describing the importance of getting the 'puzzle pieces' 'on the table' and how they relate to a unit overall. These puzzle pieces need to be defined. You need to know what the pieces look like and how each is defined. Once this is accomplished, it is more likely for a designer to determine how they fit together. Jill and her team attempted to do this by creating large posters with a variety of phrases and activities listed under a heading for each day (see Figure 4.13).

Figure 4.13: Curriculum design artifact, lesson planning outline.



As will be outlined below, teachers struggled with defining the various ‘puzzle pieces’ they were trying to fit together.

Matt’s efforts at trying to determine which materials would be used during the final design challenge occupied much of his time during curriculum design. He was not able to move on to this point until the team initially had a unit idea.

- Daily Teacher Reflection – Matt (Day 7): At the end of the day today we are left with an idea for a challenge that we are all excited about, so I think our next step is to really hit the ground running with what we want to include in the unit, what concepts we want to focus on, and how we are going to implement the design challenge.

For Matt, the idea or starting point was there. What was needed next was to figure out what the ‘pieces’ looked like and how they fit together. Matt was very dedicated to the task but struggled with being able to clearly articulate which materials students would be manipulating during the design challenge, and for what purpose.

- Matt: I think it's like a great idea. I just think we need to refine it just a little bit more. Maybe add some different constraints or maybe tweak it just a little bit so we have more of a design component involved.

The idea Matt is discussing here involves giving students a base vehicle upon which they can ultimately design their rescue vehicle's propulsion system and movement mechanism (e.g. treads, wheels, etc.). However, it was not fully 'refined'. He sees the potential of how the proposed idea could work, but the logistics and details are not entirely defined. Derek can be seen below having a similar conversation with his team, this time in regards to the unit as a whole.

- Derek: Well I think the way we've been talking…we want there to be this discovery piece in there…we want them to be able to talk about the systems in a bike and all the pieces and how they move together and how they move separate. How each piece works and so I think a big part early on is maybe, I mean…part of that…I don't know…do we jump into background science right away? Or do we jump in how a bike works right away?

The team has proposed a variety of BA's that students could experience during the unit prior to the design challenge. Derek is almost hoping that the design process will organically grow out of these pre-determined BA's involving different systems or pieces of a bike. However, each previously discussed background activity has only been discussed, not written out. The specifics of what each lesson encompasses are not well known or understood. It therefore makes it more challenging to determine which BA's are appropriate and the order in which they should go.

When an idea or components of an idea are not well defined, it is personally frustrating and equally damaging to a team's ability to move forward with the design process. Sammy, who was asked to develop one idea for her team to consider, portrays exactly how challenging it is to move forward with an idea when it's only been described in conversation and not well understood by all members of the team.

- Sammy: So like at this point I just…if we're like if we're gonna talk about the idea, I want help brainstorming it rather than like…I think we've thought of a lot of questions, let's work as a team to brainstorm solutions together or change it. Because my brain…I can't like, I'd like a break from thinking about like you…I either want to do it more together, like thinking of solutions um…

The proceeding exchanges to this outcry were questions and criticisms of the idea Sammy was outlining. For Sammy, the idea was somewhat developed, but not to the point where she could easily answer the questions and criticisms her team was throwing her way. She then became frustrated. She could not think about it anymore. She felt the team needed to jump in and help her defend the idea because she had developed it as far as she could. When a team got stuck, as Sammy did above, a coach was usually relied on to help the team move forward.

- Nick: There are lots of times you get stuck, so when they get stuck I've been trying to reassure them that getting stuck it part of it and that we'll be able to find our way thru it or something like that. It's again a healthy balance because it's like there's definitely things that are majorly missing from the curriculum.

Nick experienced firsthand with his team what it was like to get stuck. When an idea does not work and you cannot move forward, it is difficult. As Nick states, it is ‘part of it’, but it happens. The key portion of this statement comes at the end when he admits that there are parts of the curriculum that are ‘majorly missing’. This happens when a team fails to develop an idea because they ‘get stuck’. One of the main reasons for getting stuck is ill defined ‘puzzle pieces’. It is hard to move forward when you do not completely understand what you are working with.

Teachers were able to identify that certain parts of an idea needed to be further developed. What was less likely to occur was action taken as a result of this realization.

- Matt: So then it sounds like what we really need to do is think about what challenges we want this thing (the unit) to accomplish. And then figure out how we could work different forces into those challenges. Like if we have a hill…that could be gravity. If we have different surfaces, that could be different amounts of friction. So I mean I think if we design the challenges in certain way that can really allow for different types of forces.

Matt identified a viable action plan to help the team decipher what lessons should be included in the unit leading up to the final design challenge. He knew that the ‘puzzle pieces’ were there he just did not know what they looked like. Later on, Matt again identified a problem that the team was facing, this time in regards to the final design challenge.

- <u>Matt</u>: Now the only thing I am kind of a little, questioning about this is will the designs of the kids be different enough like varied enough…but at the same time I don't really know any way around that because it would hopefully…different kids will choose different forces and that's one of the reasons why I was trying to think about how to differentiate the forces…but I don't know we'll see.

This time however, his plan of attack was less precise. He understood that students may ultimately have similar designs to propel their vehicle. What he was less certain about was how to address the issue. Which materials will students be for sure using? What types of forces will be used and how can they manipulated and quantified or measured? This proclamation gave insight into Matt’s thought processes and helped further define the importance of having a complete picture of the problem prior to embarking on a solution path. In this instance, Matt identified the problem, but was less clear about what could be done or what needed to be done to address the problem.

There were limited exemplars of teachers putting into place strategies or action plans to aid them during the curriculum design process. One specific support, UbD, was seen as a possible strategy by Sammy to aid the team in moving forward with their curriculum.

- <u>Sammy</u>: Yeah cause in UbD we have the guiding questions…how do we get something started, how do we get something to stop moving? I think that might be a good step before we go to…it'll get us to the force of it…to the hovercraft.

Sammy attempted to help the team move forward with the activities that would lead up to the final design challenge by instituting a backwards design philosophy. She had created a set of guiding questions that she felt could help the team during the design process. Later on, she suggested a similar plan.

- Sammy: Do we wanna…like write the parts of the standards that we want them to get? Like change direction, change speed, like across a sheet of paper? And then write how we think that the materials will get them to the challenge.

  Nick: That's a good idea…I think it's a really good idea.

The team struggled with determining which materials to use and at which points in the unit they should be used. Sammy suggested starting with the content standards they were interested in aligning their unit with and moving backwards with each proposed background activity. This idea unfortunately was never actualized. The team chose not to use the strategy to help them better determine what the puzzle pieces they were discussing looked like.

***Lots of talking, little writing*.** Part of the challenge of getting teachers to move from just talking about ideas to actually writing about ideas is convoluted between this study's first and second conceptual categories. Getting teachers to write lesson plans for their own classrooms is challenging. Getting teachers to write out lesson plans for an outside audience over a specific period of time is even more challenging. During one of the final days of the PD, I checked in with Nick and recorded the following in my daily reflexive journal.

- Researcher Daily Reflexive Journal (Day 11): I talked with Nick today about this and he summarized that there aren't many lesson typed up yet. There has been lot's talked about as they hash things out, but only 5 of the 13 lessons are flushed out (or written up).

A handful of examples from Team RF will illustrate how a team can bring up the reality that they have to actually write a curriculum without actually drafting any lesson plans. Derek starts of by describing the challenging nature of drafting lesson plans amongst a team of teachers.

- <u>Derek</u>: What is this really going to look like and I think that's part of my…you know struggle right now is that…you know…working on seeing it. I see a lot of possibilities, but seeing something that we can really write together and that we can really work on together and other people can replicate down the road.

Derek is excited about the possibilities that the unit his team is considering, but is less confident on their ability to work together during the writing process. The below utterance from Jill highlights this point.

- <u>Jill</u>: Give enough clues from the group to have something to go on so you're not just writing out of your…pick an orifice.

In order to be on the same page during the writing process, it was proposed that each teacher get a bulleted list of main points to consider when drafting a lesson. Without doing this, each individual teacher is left writing on their own with little or no idea what the other members of the team are thinking. The lack of written lesson plans became more contested towards the end of the team's time together.

- <u>Jill</u>: We need to take a stab at an actual first draft as Hank knows. For me, that writing process is really what cranked things up.

During the last day of the PD, prior to the team's meeting at the bike shop, Jill proclaimed that the team needed to have a plan in place in regards to the team's first draft of the unit.

- Jill: So I would really like to finish my part in the next few weeks…that is what's expected from me for the rough draft of the project. So if there's a way to divide the stuff up like really soon, like now.

Team RF had myriad of reasons why no substantive lesson plans were written during their time together. Jill discussed the team's struggles with actually writing during her individual interview.

- Jill: Because that's really our job…to create the curriculum. And I think it's really easy to get distracted from that.

Team EttR drafted a series of lesson plans and an associated UbD document, but it was less of a concern during the team's design conversations. Team LD was the exception in regards to writing lesson plans as they completed an entire first draft of a unit with an accompanying presentation that could be used during the unit's implementation. For Rita and Evelyn, the theme was lots of writing little talking.

Glossing over the details. This last sub-theme connects the previous two sub-themes. Glossing over the details came about as teachers identified that they needed to do something or clarify some aspect of their unit without actually moving beyond the identification phase. This, coupled with the lack of interest in writing out any of their ideas for other to read, interpret, and contemplate resulted in talk of potential action, but no actual response. In other words, it was assumed that something needed to be done and it should kind of look like this, but we are not really sure what the details are or supposed to look like. Therefore, proposed ideas remained as just ideas that never resulted in concrete action.

It was very easy in conversation to be excited about the directions a unit might go, without accepting the reality that once the direction was decided upon that the details of that particular direction would need to be flushed out and eventually written out for an outside audience. Matt precisely described this feeling of excitement.

- Matt: I am feeling pretty good about it! I'm excited about the unit. I'm excited about the context. I'm excited to see some of the ideas the kids have. I'm a little nervous exactly how were going to implement it, like exactly what we'll do with the engineering challenge and everything, but I still think we have a little bit of time to figure some of those details out.

As the end of the PD neared, Matt's excitement and comments changed as he and his team had still not figured out precisely how the design challenge would work.

- Matt: Well I mean I think, within the next…well you know we would obviously have to come up with some sort of solid idea, but I mean even if it's not done by the end of next week or whatever I still think as long as we each have a direction where we're going, we could just assign jobs for us to do. So I mean we're not…I don't think we need to finish it by any means or…

He is hopeful at this point that once the idea is determined, he and the team will be able to 'assign jobs' and begin the writing process. Skimming over the details and hoping that major events would be accomplished in the future were commonplace across two of the teams. Teachers would put off writing out or taking action on both big and small tasks.

Early on in the process Matt had the idea to have students work on a BA involving friction somewhere in the unit.

- Matt: I'm going to make another card just for the sake of getting all our ideas out there. Some sort of friction experiment involving treads cause then that would give them an experiment with treads. But I don't know how we would set that up so I'm just going to put treads and a question mark (laugh).

What exactly this idea would look like would be put off to a later time. Evan, of Team RF, can also be seen below putting off a proposed idea to a later date and time.

- Evan: Derek had this idea that maybe we could jigsaw (it) then we thought of what if we thought of this as one project for the whole bike. Then we could have them (student) focus on different elements (of the bike) so one team would be figuring out what's the best way to balance the bike. I'm not really sure what those components are yet.

Something about what Derek had suggested for the jigsaw clicked for Evan. All of a sudden this made an idea possible. However, the team and Evan have not quite figured out what the different components of the 'jigsaw' will be. They see that it can work in their classroom and they run with it. Jill, who was standing next to a large poster she created glosses over the details with the following suggestions to the group.

- Jill: I like to…I like what you're saying. I'd like to really start with that tomorrow. I think we can start to chunk up…like here can you imagine so here's treads, and I won't go into it…so like this is one of the concepts it's like the surface area and there is actually information about the science of it. Like what it means to have the wider tread. So I can imagine a lesson where you had bikes with different kinds of tires.

Her proposition is to start tomorrow. She sees how each lesson can possibly work, though she 'won't go into it' now. Aside from writing a few daily goals and possible activities each day of the unit would compromise, the team never did flush out Jill's proposition. It was put off to a later time and the team had a set amount of time together. One last example from Derek, who was trying to determine a suitable data measurement activity, states the following.

- Derek: I truly think that if you, if you pick the core science concept that you can get some kind of demos or some kind of activity with that and find the data collection that goes along with the activity. I think that doing that with a single activity even if it's with a couple days of an activity.

Here again, there will be 'some kind of demo' or 'activity' that students can collect data. What exactly that looks like will be determined at a later time.

Theme summary: Curriculum design directions. The preceding theme identified specific challenges that teachers encountered during the design process. The purpose of describing and outlining the most frequent challenges teachers encountered during the curriculum writing process is to open up some potential areas for further exploration and support that could be provided during the design process. As previously discussed, teachers can bring invaluable insights and immense value to the design space, but they typically do not view themselves as designers nor do they engage in the design process with a lot of experience writing curriculum for an outside audience. Helping teachers and coaches make decisions, write instead of talk, and address problems when they arise should allow for a more useful and better design curriculum that has the ability to be taught in any classroom, not just the select few of the teachers who developed the curriculum.

Theme 3: Provide teachers with insights into how teachers use curriculum. The last theme emerged upon identifying a trend with Team RF. There were a few key exemplars where teachers would be discussing and contemplating how other teachers would presumably use the curriculum they were designing. These exemplars stood out. The limited examples discussed below tie in nicely to the last category and provide a final avenue of exploration to aid teachers during the design process.

I use curriculum different than you. Teachers use curriculum resources differently and most teachers recognize this. Below, Evan described how he himself has relied on various aspects of a curriculum, while also noting his tendency to adapt the materials when needed.

- <u>Evan</u> Cause you're taking…you're going from scratch. So yeah…a lot of the times if you have your classroom and you're working with a curriculum, well that's a lot of assumptions (that) are pre-built and a lot of the directions are pre-built and you can take and spin it and make it your own but this comes from…there's nothing before you start.

Evan's response here is genuine and prototypical of how most teachers would utilize a curriculum. The challenge for him and his team during the design process is that they are no longer afforded the luxury of having 'pre-built directions' or 'assumptions' to build from. As Evan says, 'there's nothing'. Unfortunately, teachers are not familiar with the current research trends in regards to teachers and curriculum. They therefore rely on past experiences with curriculum resources when contemplating how to design a curriculum for an outside audience. Jill describes her strategy for borrowing a lesson or two from a curriculum and slightly acknowledges her belief that most curricula are 'designed' for teachers to simply take a lesson or two for their classroom.

- Jill: It's designed to be for anybody to say…oh I think I'll use one lesson or two. There's no way I'm going to fit…

Michelle, during her individual interview also described how she would be using the curriculum her team was co-designing.

- Michelle: Once I see the final product, I'll be cool. Then I'll go with it. Then I'll do tweaks on what I think is gonna work for me and my kids.

Regardless of what the final written curriculum looks like, Michelle will make her own 'tweaks'. Her tried and true strategies for adapting curriculum resources for her classroom give her confidence in what the implementation will look like moving forward. Michelle and Jill, as evidenced above, were well aware that they would adapt the unit once they implement it. Below Derek identifies the purpose for writing the curriculum, something every teacher was aware of.

- Derek: The whole point of us writing this curriculum is to share (it). That's why we're doing this stuff.

There is a disconnect here. The teachers inherently know that they will adapt the curriculum they are designing for their specific contexts and they realize that they are attempting to design a unit for an outside audience. The disconnect lies in their lack of awareness of the variety of ways instructional designers plan and write curriculum resources coupled with a lack of understanding how teachers actually use curriculum resources. Evan, upon realizing that each member of his team would be implementing the unit differently suggested the following.

- Evan: If we can build…kind of the…you know there might be different ways that we can implement and it might be good to do it differently as far as the research goes… to provide each other the option of being able to diverge depending on what our classrooms are configured like.

  Jill: It seems like we could…whatever we write, that will be what you guys are doing and then…which we didn't do such a good job last year but I think we can do better this year. If I do it differently that'll be just like the teacher notes or enrichment or something like that.

Evan and Jill feel that if they do implement the unit differently, it might be good for the 'research'. It will give the unit more 'options' and divergence points.

Ultimately it comes down to getting teachers to view themselves as designers. Instead of acknowledging that each of them will implement the unit differently it may be beneficial to have teachers consider research related to how teachers use curriculum resources and how instructional designers plan and develop curriculum. Without providing teachers a glimpse of the options and research related to designing curriculum for teachers they will continue to occupy the design space as teachers, not designers.

Theme summary: Provide teachers with insights into how teachers use curriculum. This brief theme demanded a space in this category because of the value I felt it could potentially have for teachers during the design process. One last exemplar from Michelle highlights exactly what can happen when teachers are treated like and view themselves as teachers during the design process.

- Michelle: I'm listening but…if they're gonna have like this debate and stuff and I know I don't need to be part of it then I'll do my own thing.

For her, key 'debates' are not of concern. She can sit out on these conversations. She will be teaching the unit her own way. It is possible that she would be more vested in the design process if she considered herself a designer and understood the value of having 'debates' about key aspects of the curriculum her and her team were developing.

Conceptual Category Summary: Possible Avenues for Exploration

The final conceptual category was included to point to possible aspects of team-based, teacher-centric curriculum that could potentially be addressed to further develop teachers to consider themselves as designers who also teach. By introducing three concentrated areas and associated trouble spots that could be addressed, the aim was to pragmatically identify aspects of the curriculum design process that were challenging, difficult, or potentially unknown to all participants in the study.

Theoretical Assertion Summary

This study's major theoretical contribution emerges from the understanding that teachers will enter the design space as teachers first and foremost, and that facilitation serves as a beginning point to assist teachers espousing to be designers, but it is insufficient to move them beyond thinking of themselves teachers. The call to address specific aspects of curriculum design involving teachers was introduced via the study's third conceptual category. Again, the aim of the assertion is that treating teachers as designers and inspiring them to move outside of their comfort zones will allow for a more beneficial design experience and overall product. *Teachers need encouragement to innovate and design for outside audiences during the curriculum design process*.

Chapter V will further discuss the study's major theoretical assertion and relevant literature. There will also be an implications and future research section that further discussing teachers, coaches, and curriculum as it relates to the study's findings.

Chapter V: Discussion, Implications, and Future Research

Chapter V responds to the study's research questions by discussing the data presented and analyzed in Chapter IV. The chapter is split into three sections, each connected to the study's major findings and relevant literature discussed in Chapter II. First, the major theoretical assertion from Chapter IV is further developed in connection with the relevant literature. The last part of the chapter includes the study's implications and future research centered on teachers, coaches, and curriculum.

Discussion

Curriculum design is a process that encompasses more than creating a tangible product for classroom use. In line with the writings of Remillard (2005) and Brown (2009), curriculum takes on a participatory relationship with teachers and curriculum materials represent meditational means or cultural artifacts that either afford or constrain student activity. In deciphering the criteria for acceptable solutions to an ill-structured, complex design problem like STEM-integrated curriculum design, teachers must "construct personalized systems for evaluating their products" (Jonassen, 2010; p. 80). This process exposes teachers in a way that they may not be personally prepared to deal with. Again, as Remillard (2005) notes, "for many teachers, the process of interacting with a new curriculum is neither explicit nor public" (p. 239). This contrasting reality takes center stage when asking teachers to design a curriculum for an audience other than their own. If teachers are ill-prepared to explore and actively discuss (Remillard, 2005) their personal views and systems for processing STEM in their own classrooms, the curriculum design process will be riddled with obstacles, challenges, and design problems that will persists if not adequately addressed.

Curriculum design is a design problem. Integrated curriculum design is a design problem (Jonassen, 2000; 2011). By inviting teachers to participate in the design process, one needs to be aware that teachers tend to encounter this particular design problem as teachers first and designers second. Teachers are regularly involved in design work during their everyday practice as they make decisions about how best to meet their students' need in the classroom (Brown, 2009); however, they typically do not encounter a design problem such as STEM-integrated curriculum design in their everyday practice nor do they consider themselves designers (Reiser et al., 2000; Penuel et al., 2007).

The evidence presented in Chapter IV details a plethora of specific examples where teachers and coaches were asked to be designers and take on ill-structured and wicked design problems that had no obvious answer or solution path to pursue. Quite often teachers and coaches were perplexed by the problems they were facing. To solve the problems encountered during the process teachers frequently attempted to rely on past experiences to help them through the design problem. Actions typical of this observed behavior included designing for their own classroom contexts, compartmentalizing the learning stages, or outright simplifying the problem that was to be solved. These strategies were more or less unsuccessful as each team encountered myriad problems that were never fully solved or addressed.

The variety and complexity of problems each design team encountered arose as a result of the need to integrate multiple content standards from multiple disciplines combined with the requirement to work in a team with the intention of designing a curricular unit for an outside audience. As each team would hit the wall and come to a decision point, reflection on and reflection for action needed to occur as has been advocated for novice designers during a design task (Hong & Choi, 2011). Potential ideas needed to be explored in full with the intent of bringing a solution to the team for consideration. Placing each team in a position to make an important decision put each team and individual member into the role of evaluator. Evaluations needed to be made and personal visions and perceptions needed to be discussed. As Remillard (2005) states, teachers needed to, "examine a new curriculum with (their) colleagues, making their interpretations and decisions explicit to themselves and others. A central goal of such an activity would be for teachers to openly and actively engage in participating with a curriculum" (p. 240). This participation with the curriculum is not and cannot be superficial because it requires personal evaluation of the proposed solutions (Jonassen, 2010) to the design challenge in front of each team and teacher. This type of activity engages teachers in a, "form of ongoing inquiry and professional learning" (Remillard, 2005; p. 241) that benefits the endeavor's end product and the teachers involved in creating the curriculum (Ball & Cohen, 1996; Borko, 2004; Parke & Coble, 1997; Schwartz & Gwekwerer, 2007).

The teachers in this study were the primary decision makers of their team's designed curriculum. In order to find acceptable solutions, the team needed to have internal and external curricular consistency (Huizinga, 2014) to aid them in determining how their personal evaluations would shape the curriculum they were designing. In other words, each team needed to actively discuss their own visions and conceptions of the unit's purpose while considering how each design decision would either constrain or afford their students' learning once the unit was finished. Again, as Jonassen (2010) states, "the criteria for acceptable solutions are not always obvious, designers must construct personalized systems for evaluating their products" (p. 80). It is therefore predicated that teams examine their own visions of a unit's purpose together with the aim of exposing their own personal understandings and ideas. To do this, teachers must interpret, modify, and construct personal meaning of the interactions (Blumer, 1969) that are occurring while working with their team. The goal of allowing this meaning making to occur amongst your teammates is to make the abstract and unknown more accessible and visible to everyone involved. This aligns precisely with Remillard's (2005) notion of "curriculum conceptualization". Jonassen (2010) highlights the perplexing nature of this challenge by noting that design problems are, "very ill-structured and complex…(and) require the problem solver to engage in extensive problem structuring, often using artificial symbol systems" (p. 80). Each teacher in the study was involved in highly complex work that required him or her to be personally invested in the decisions that were made regarding the design of the unit. They not only needed to attend to the task at hand, but also needed to vocalize their thoughts and ideas with their teammates. It is therefore permissible, given the study's main theoretical assertion that curriculum design encompasses more than previously understood because of the challenging nature of the work and the essentiality of teachers to be personally exposed and engaged during the process.

Curriculum design encompasses more. Curriculum design encompasses more challenging work of each teacher and coach involved in the process than one may be aware of or wish to acknowledge. This again arises because, “the process of interacting or participating with a new curriculum is neither explicit nor public” (Remillard, 2004; p. 240) for each participating member. If the task is approached without realizing the importance of conversation and interaction with each proposed idea, activity, or lesson; the process will fail to produce anything of significance due to lack of purpose or vision embedded within a unit’s overall design. When teachers are not asked to discuss and openly interact with each other during the curriculum design process, familiar and hollow learning experiences will be created. Teachers need to be personally vested and focused on a unit’s overall purpose because curriculum is a cultural artifact (Wartofsky, 1973; Brown, 2009) that encompasses something more than a written plan of action.

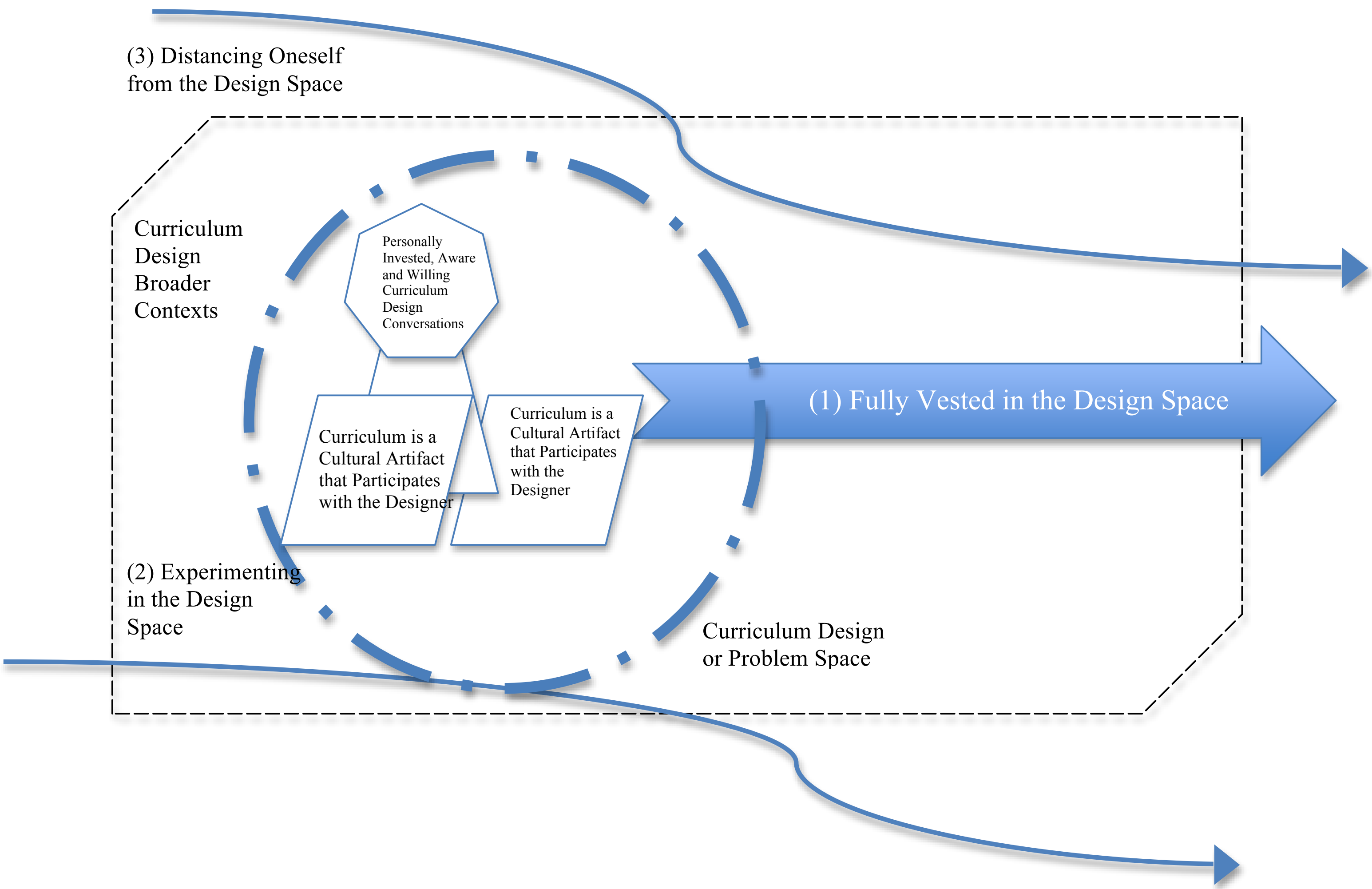
The curriculum that the teachers in this study created were to be written for classrooms beyond their own. Their written out lesson plans, overall unit goals, and associated student activities declared what they thought STEM integration should be and how it should play out in other teachers’ classrooms with students they will never meet. Each team’s curriculum resources would afford or potentially constrain a teacher’s actions (Brown, 2009). This realization, whether openly discussed or not, is more meaningful on a grander scale because it has the potential to afford or constrain student actions once they engage in a unit’s learning activities once the curriculum is implemented. And while all teachers in the study were aware of how adaptable and modifiable curriculum resources could be once they were in the hands of a teacher prior to and during implementation, they knew that that starting point was significant. It was significant because it had built in assumptions about what STEM was supposed to be, it was significant because it was supposed to contain definitions, learning objectives, and student assessments, and it was significant because ultimately it would be used in someone else's classroom with someone else's students.

The process of declaring your preferences, vision, and understandings of a reform movement by writing out a curriculum says more about who you are as a teacher than one would assume or perhaps admit. The act itself puts you out there. It exposes you. Just as Remillard (2005) and Brown (2009) have noted the participatory relationship that exists between teachers and the curriculum, this study's findings further expand this relationship to also include teachers' participation with self-designed curriculum resources during the curriculum design process. Denying the existence of this relationship is disingenuous given the results of this study. Simply providing teachers with frameworks, definitions, and assessments of a curriculum's progress is not enough to overcome the exposure risk teachers encounter during the design process. Facilitation in and of itself only initiates the process; it will not overcome the more difficult challenges inherent within the task. As Remillard (2005) states, "information about the curriculum is not sufficient" (p. 239). Instead one must promote deep conversation and inspire teachers to personally insert their ideas, activities, and vision for what a STEM-integrated learning experience should or could look like. Curriculum resources need a backbone or foundation upon which to operate; in other words they need a designer. Whether or not the designer is a teacher or not, is irrelevant. What matters is that a curriculum be designed and authored by someone willing to say something about what matters most, not a loose string of activities that have been used in the past or borrowed from somewhere else. The integration of STEM is just beginning in elementary classrooms across the country. Any curriculum resources that get disseminated need to be carefully considered and perhaps considerably different than curriculum typical of the past. When teachers enter the design space as teachers first and designers second, a more lackluster and predictable curriculum will be designed.

Engaging in the curriculum design process as a team therefore requires that meaningful conversations take place. The willingness to embrace and participate in these conversations is a choice to be made by all partaking in the process. Coaches also have a connection to the curriculum in a way that moves beyond simply creating a tangible product for external use. Coaches, who at one time were likely teachers, also work within the same participatory relationship with the curriculum as the teachers they work with. They too must also assess potential solutions to problems as they arise and provide feedback, evaluation, and opinions about any proposed action to the problem at hand. However, being in a different role than that of the teachers, a coach (and also a teacher) can choose to take on this predicament in one of three ways. A discussion of each of these approaches follows.

Pathways through the curriculum design problem space. When teachers and coaches are not comfortable being designers of curriculum materials, a variety of strategies or "pathways" will be exhibited during the design process. Figure 5.1 outlines the three exhibited pathways as evidenced from the data. The figure takes into account the reality that curriculum design is a design problem and that in order to fully participate in the task, one must openly and honestly acknowledge the participatory relationship that exists between teachers and the curriculum while accounting for the expanded role curriculum resources take on once implemented in the classroom. Taken as a whole, the inner dashed circle of the figure, represents a design space where teachers are fully vested in discussing a unit's overall purpose and vision while being aware of the fact that their own personal insights and suggestions will be used to evaluate the curriculum resources they are espousing to make.

Figure 5.1: Three pathways through the curriculum design problem space.



Participants in this study, teachers and coaches, were all immersed within the constructs and contexts of the PD experience that the design space was surrounded by. That is, everyone participated in one way or another in the activities developed and implemented throughout the PD. This is taken into account in Figure 5.1 via the dashed line that forms the outer perimeter of the figure. However, not all participants participated equally within the design or problem space that resulted from the design problem placed in front of each team. The following three sections will outline and describe each of the three “pathways” participants “walked” during the study with the aim of answering the study’s overarching and underlying research question(s).

Engaging with the design and problem space. Acknowledging and engaging in the design space and problem space requires that participants be responsible for identifying potential problems as they arise and that they actively and earnestly search for solutions to the design problem uncovered during the process. Participation at this level does not require that participants maintain or walk this pathway and only this pathway. It does however imply that at certain points in the design process participants engage in behaviors typical of this pathway.

There are exemplars from the data in Chapter IV and those that did not make it into the chapter that describe and portray the behaviors and actions of teachers and coaches exhibiting telltale characteristics of this pathway. To begin, participants that walked this pathway were willing to divulge and vocalize their thoughts, ideas, and feelings about a unit’s purpose or vision. In doing this, participants attempted to demystify, disentangle, or otherwise remove some of the angst surrounding a proposed action or idea that would otherwise be bottled up inside their heads subject to interpretation and assumption on the part of their teammates. Talking about proposed solutions allowed participants to conceptualize a curriculum's overall purpose and intricate details for the benefit of the designer, his or her teammates, and the unit as a whole.

In addition to talking about and vetting out a potential solution to a problem, for example the need to design an assessment related to a unit's final engineering design challenge, participants that engaged at this level also *acted* in addition to talking. In regards to the previous example this could involve unwrapping a particular set of benchmarks and designing an assessment (e.g. scoring rubric) that aligns with the benchmarks a proposed activity was to be aligned to. Depending on the task, most participants found opportunities during the design process to take action on and thus took responsibility for an aspect of the unit's design.

Experimenting with the design space. Experimenting with the design space is defined by acknowledging the existence of a design space and perhaps the existence of design problems; but is defined by the choice to move forward from this point differently than the other participants on your respective team. Again, this pathway was one exhibited throughout the study and was never completely actualized by one specific person during the study. Rather it was reified by a variety of people at varying points during the PD. It was a choice, or pathway traveled, that was made when times were tough and decisions were needed or actions taken.

Facilitation can be considered somewhat prototypical of this pathway, in that the person facilitating a team could help a team identify a problem or examine a particular set of solutions; but the process of acting on any proposed suggestion for action is not his or hers. Instead, the search for answers or the need for action is taken up by someone else, not the coach or facilitator. The facilitator guides or assists the team during the curriculum design process, but does not take on the responsibility of actually designing a solution to an identified problem. Chapter IV presented and described how all participants exemplified and walked this particular pathway. And while there appears to be no inherent issue with being a facilitator, the data here suggests that there may be personal inner conflicts and noticeable differences in how all participants of a team are engaging in the process. A coach walking this pathway is fully aware of the conversations that are being had, the complexity of the design work being attempted, and the unknown territory needed to be explored to find a solution. However, given their different position or role within the group, a coach who is a facilitator will be more often than not be on the outside looking in when walking this pathway.

For example, there were instances where coaches identified or played out specific roles during the design process that resulted in torn feelings about what his or her role should be during the design process. The pivoting point of this inner dilemma revolved around whether or not they should be engaged in the problem space in the same manner as the teachers they were participating with. Teachers were well aware of the typical actions and roles coaches were to take up during the design process and portrayed mixed feelings about how this played out in regards to their team's overall unit design. The need to involve their coach on a level above and beyond one of merely facilitator was exemplified throughout the data amongst all three coaches. Coaches that portrayed this behavior briefly interacted with the design space and those in it, but would quickly retreat to a space outside of the design circle once they discovered what was being discussed or considered. Actions typical, but not limited to this pathway include: leaving digital comments on written lesson plans without taking part in the writing process itself, dropping in to 'check in' with a team and suggest possible solutions or ideas to purse and then physically or mentally leaving the space by walking away or disengaging from the problem once the rubber hit the road.

Teachers, in addition to coaches, also walked this pathway, though not as frequently or overtly. This came about due to the team aspect of the curriculum design and the choice to engage or not engage when key aspects of the unit needed to be decided upon. The choice to sit back and let others *drive*, for lack of a better word, resulted in many teachers putting in their two cents regarding an issue and going along for the ride thereafter. There was no single unified reason for slightly engaging in the design space as a *passenger,* though it was slightly connected to the realization that whatever transpired in your own classroom would be what you wanted to do. It was therefore less important what happened in the here and now. Other exemplars that included teachers walking this pathway typically involved off-loading, or allowing portions of the unit to be picked up by curriculum resources teachers had used in the past or calling upon activities from the PD that could be potentially applied to the unit the team was aspiring to design.

Distancing oneself from the problem space. This last pathway typically overlooks the existence of a design problem and the design work involved in STEM-integrated curriculum design. Once this pathway is chosen, it is not impossible to walk another; but, it becomes increasingly more difficult to interact with the design space differently the more often you walk it. This additional attribute of the pathway makes it more detrimental than the other two options because it disregards the work being done and portrays a lack of engagement in the process that other members of the team quickly pick up on and pay attention to. Both teachers and coaches exemplified this pathway at varying points throughout the design process. In taking up the pathway, a teacher or coach would fail to meaningfully contribute his or her ideas to the task at hand. You are not personally vested in what happens and therefore have no ownership or bond to what gets ultimately gets produced.

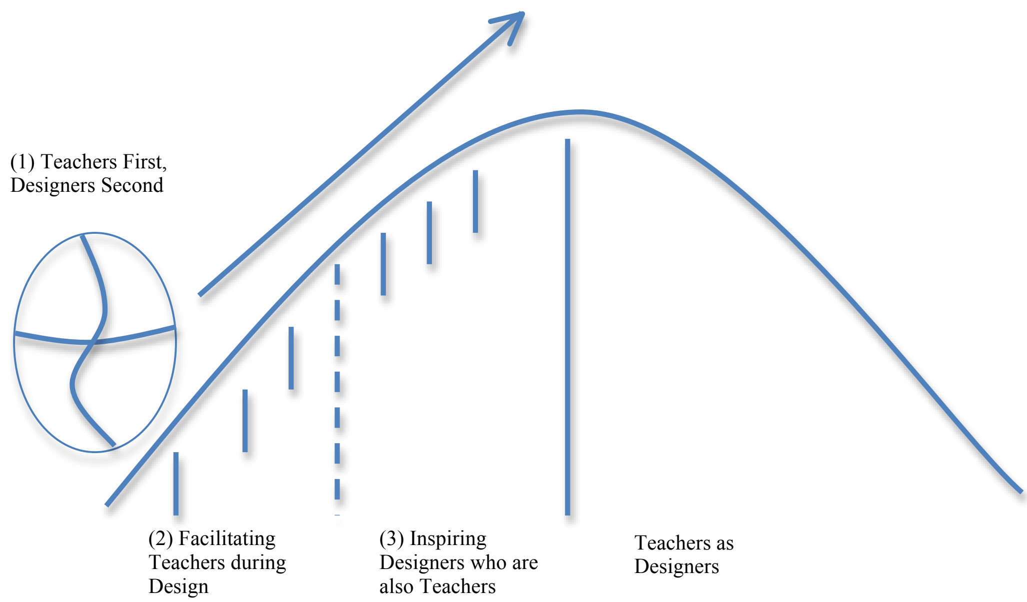
Walking this pathway creates a number of problems, for example only leaving digital comments on drafted lesson plans and not actually writing documents for the unit. In sum, this pathway allows participants to disengage from the design space and design problem created during STEM-integrated curriculum design by allowing a person to become an onlooker or outside observer. For reasons unbeknownst to the team, teachers or coaches who walked this pathway were unwilling to acknowledge the design space in and of itself and therefore engaged in the curriculum design process without truly contributing in a significant way. Participants who walked this path may have had valuable insights, suggestions, or solutions for the team to consider, but for reasons beyond the scope of this study chose not to fully engage or divulge their ideas with their team.

It was unfortunate that teachers and coaches exhibited behaviors and actions typical of this pathway. The aim of the PD and curriculum writing support was to foster the pragmatic understandings and skill sets present amongst practicing teachers culminating in the designed units they co-developed. Unfortunately, it was not always possible to engage teachers or coaches in the design process in a manner that benefited the team or the curriculum they were creating.

Encouragement to innovate and design for outside audiences. This last section will connect Figure 5.1, and the associated discussion related to each respective pathway, to the study's major theoretical assertion while transitioning into the implications and future research sections of the paper.

Examined together, Figure 5.1 and Figure 5.2 (copied from Chapter IV) compromise the study's major findings. Recall that Figure 5.2 depicted a figurative "hill" that was accompanied by an equally figurative "ball". The simplistic nature of the figure, by no means intends to oversimplify the complexities and individual personalities that generated the theoretical figure. Rather, the aim of the figure is to call attention to the all too frequent request to have teachers take on the role of curriculum designers in addition to being teachers, and the equally likely possibility that teachers will be only facilitated or assisted during the process. Figure 5.1 depicts two possible pathways (numbered 2 and 3) facilitators can walk during the process, but also identifies a central and important pathway (number 1) that more individuals could traverse if they were truly interested in helping teachers design the best curriculum possible. This central pathway would ideally be taken up by everyone on the team and would be maintained throughout the duration of the design process. The more often this first pathway is chosen, the more fruitful the conversations will be. The more conversations that are had, the more concrete the team's understanding about a unit's overall purpose and place as a cultural artifact to be played out in classrooms other than their own will occur. This, in and of itself will lend itself well to the upper portion of the initial incline of the hill in Figure 5.2. This occurs because once teachers are accustomed to and expected to walk this central pathway, they will take on the task as designers who also teach, rather than teachers who were asked to be designers. Once this occurs, innovations are more likely to occur as something personally meaningful is created, designed, and evaluated. Again, this central pathway (represented by the large arrow) will further enable those vested in working with designers who also teach to better develop their own skill sets, strategies, and supports to aid a design team vested at creating a curricular unit. The more often that we bring teachers and coaches into the design space and the more frequently that we encourage them to be designers and innovators, the more developed our understanding of team-based, STEM-integrated curriculum design will become.

Figure 5.2: Encouragement to innovate and design for outside audiences.



Implications

This section presents a series of connected implications related to the study's primary participants and the product they discussed and developed. The aim of each sub-section will be to highlight associations and suggestions that emerged as a result of the data collected and analyzed in conjunction with my own subjectivities and professional views.

Teachers. Teachers will inevitably enter the design space and problem space as teachers before considering themselves designers. This is fine and if anticipated can be addressed early on in the design process. The PD activities and curriculum design supports that were put into place during the 12-day span of the study modeled those traditionally experienced by the teachers in the study. And while it was not this study's intent to evaluate the effectiveness and appropriateness of the PD model put in place to support the curriculum writing process, I feel confident in stating that there was a mismatch between what was being asked of the teachers during the PD and what actually needed to occur. Teachers were largely treated as teachers first and designers second. In order to reverse this relationship, an extensive look at the potential connections that may exist between science teacher PD models and the line of research associated with “design thinking” (e.g. Plattner, 2012) is needed. Reversing the top-down approach of PD models specifically espousing to address STEM integration and curriculum design will not be easily accomplished. The problem, and what is needed to solve the problem, is something very different than any other problem faced by teachers, researchers, and PD providers in the past.

In making the decision to purposefully involve teachers in the curriculum design process, one needs to be cognizant that teachers will be now taking on the role of designers, faced with a taxing and challenging design problem. And while there may be pedagogical strategies and activities that are beneficial for teachers to learn and experience during the design process, this and this alone will not be enough to effectively overcome the task at hand: STEM integrated curriculum. The benefits of working with designers who also teach, as opposed to teachers who were asked to be designers may seem trivial, but this study’s analysis and findings suggest it may be pivotal. The myriad of problems each design team experienced during the design process needed individuals willing to think as designers who also teach, not teachers who were asked to be designers. The third conceptual category (*Possible Avenues for Exploration*) from Chapter IV provided a glimpse at some beginning areas that could potentially be addressed to help teachers during the curriculum design process. If we want to continue asking teachers to design curriculum resources for their own and other classrooms, we need to begin supporting them as designers and not expect them to produce a product that we ourselves have yet to fully conceptualize.

In order to have teachers enter the design space and engage fully with the design problem they are facing, teachers need to be willing and able to be personally invested in the process. This requirement cannot be taken lightly because the type of assessment needed to evaluate the worth of any designed product needs to come from the designers themselves. Herein lies the difficulty of this problem. By personally engaging in the design process, a teacher needs to personally expose his or her own beliefs about the product being co-developed. This participation with the curriculum being developed and the need to actively discuss one's own beliefs about what should or should be not taught in the unit will undoubtedly expose teachers in an unfamiliar manner. There is emotion involved: identity, and territory. And while it may be possible to sneak into the design space on occasion without exposing your true intentions or thoughts, the team's overall functioning end product will be disadvantaged when this is attempted. When every teacher on the team is personally vested in the design process and willing to openly and actively discuss his or her own interpretations of each proposed idea, a true "solution" will be happened upon at the end of the design process.

Finally, given a teacher's past experiences that will pervade throughout the design process, one needs to consider these as a jumping off point and not a potential answer to the problem at hand. This study's findings parallel others that have identified that a teacher or novice designer typically approaches design problems with a solutions-driven approach (Boschman, McKenney, & Voogt, 2014; Hong & Choi, 2011). Each teacher's own perceptions of what could or should be written into a curriculum will be influenced by their past experiences. These past experiences provide valuable insights and suggestions that may potentially be worth consideration for the group, but it by no means should be the given answer. For example, if a teacher has a suggestion about a lab activity that intricately ties in data analysis and a specific scientific concept (e.g. gear ratios and simple machines), it should not be uniformly applied to the task at hand. Instead, it should be evaluated and criticized based on its applicability to the problem, while keeping in mind the curriculum's larger overall goals and design. Only after this occurs should the suggestion, with or without adaptation, be considered for use. This is exactly the firsthand knowledge and experience a teacher can bring into the design space that is invaluable and not easily outsourced. However, it needs to be applied appropriately to the situation as it presents itself, and not as a panacea of solutions to each and every design problem that the team encounters.

Coaches. The role a coach takes on in a team is a pivotal aspect of team-based curriculum design. Given the ability of a coach to assume a role that differs from the other members of the team, it is important to consider what that role should be. Given this study's results, it is plausible to suggest that a facilitative role will only get a team so far during the design process. Facilitation is a starting point for supporting teachers during the curriculum design process; but without agitation or encouragement to design something innovative and valuable for larger audiences, will result in a product that is only valuable to the designer. This can be attributed to the designer's original intentions and prerogative during the design process. A coach that is able to work with a team in a manner that moves beyond facilitation is therefore justified. Most teachers will not become full-fledged curriculum designers at any point in their career. A coach who facilitates may foster and develop a teacher's curriculum design skills, but in doing so can potentially hinder the curriculum being developed and create dissonance amongst members of the team. Given the nature of this study, and the amount of time that teams actively met and worked on developing a curriculum, it would have been beneficial to all involved if coaches and teachers had embarked on the journey while equally contributing to solve the design problem set before them. Facilitation alone was not enough. The teachers needed a motivator, a critical eye, or the opinion of another coach that was asked to read and provide constructive feedback on any written documents the team had written. The team needed a partner that was equally vested and determined to work with the team with no strings attached. This may have resulted in more teams designing and developing a curricular unit that could be implemented in any classroom context and it also may have allowed more teams to address the variety of challenges they encountered during the design process (e.g. decision making, exploring multiple solution paths, etc.).

As a coach, maintaining and displaying a role that is equitable to the other members of the team possesses a value greater than any other idea, suggestion, or story you could bring to the team. This could potentially alleviate some of the tensions, and associated choices, each team and individual participant exhibited during their time together. It was clear to all participants involved that every coach was portraying and acting upon the facilitative role that they were instructed to take on during the design process. This realization resulted in varying pathways or choices being made by each coach, and most teachers, during the design process (see Figure 5.1). It may have been beneficial for a coach to assume a facilitative role at specific points during the curriculum design process, for example at the end of the day or when key decisions needed to be made. If possible, it may also be beneficial to have another coach take on a facilitative role with a design team at these specific points in time to help the team, including the coach, discover, reflect, and move forward during the design process. This action may alleviate some of the tension and confusion over what type of involvement a non-teaching member of the team is to take on during the design process as has been reported on elsewhere (Ippolitto, 2010). Maintaining a facilitative role as a coach for extended periods of times is difficult and mentally taxing as a coach must interpret multiple actions and behaviors that are occurring while also processing whether or not it is within their "jurisdiction" to intervene or make a suggestion.

Again, coaches have valuable insights and experiences that should be fully harnessed during the design process. When they are left feeling as though they are only supposed to be facilitating a teacher's design skills instead of equally collaborating with a design team attempting to solve a design problem and co-develop an external product, challenges may arise and the task may or may not be successfully completed.

Curriculum. Curriculum design needs to be treated as a design problem that has no straightforward solution path or answer. Teachers need to be introduced to the type of problem they are facing and provided with the opportunity to discuss and reflect on the ill-structured and wicked challenge they are being asked to take on. Teachers are not likely to consider themselves designers in spite of recent efforts that suggest that teaching is an act of design, from initial lesson planning to final implementation (Brown, 2009). It would therefore be of extreme value to suggest and provide the opportunity for design teams of teachers to conceptualize and discuss the type of work they are being asked to do, as opposed to just introducing them to the task by providing them with exemplar activities and curriculum writing supports (e.g. Understanding by Design). There is nothing detrimental about allowing teachers to experience a well-designed STEM-integrated learning experience, nor is there anything wrong with providing teachers with a research-supported strategy to write the curriculum they are being asked to produce. However, by not fully divulging the type of work ahead of them, most teachers, and perhaps coaches, will struggle moving forward when they hit road blocks during the design process. They may also not be completely ready to provide their own opinion, voice, or feelings when it is required of them during any assessment of the curriculum resources they are developing. This is a key tenant of assessing a product that was created to solve a design problem largely in part because there is no right or wrong answer to a design problem. It therefore has value if a team of teachers is willing to put their own professional opinions, feelings, and ideas on the table during the curriculum design process because the product they are co-developing will be eventually used by their peers in classrooms beyond their own.

The ability to provide a voice or “mode of address” (Remillard, 2012) to a curriculum being designed by a team of teachers has value because instead of having the direction of new curriculum resources being determined by instructional designers and textbook companies across the country, it can be determined by classroom teachers, coaches, teacher educators/researchers, and scientists or engineers vested in working with teachers that are in the classroom each and every day with students. This initial foundation can then provide a research-based, practitioner-developed curriculum resource that can be adapted, modified, and transitioned into elementary classrooms across the country once the final product is disseminated to a larger audience. Curriculum resources that fail to bring in a designer's thoughts, feelings, and evaluations have no real voice or value above and beyond their own classroom because these aspects of the curriculum get preserved within the designer's own head and never written into the curriculum they are co-developing. The potential audience for any curriculum resource being developed will undoubtedly be able to pick up on the lack of substantive content being purported in a curriculum if it contains no unified message, value system, or beliefs. This is where the value of involving designers, who also teach, in the design process lies. However, by not acknowledging the design problem being attended to, and not suggesting that teachers be personal vested in the written documents they produce, one robs them of their ability to have anything meaningful to say about incoming reforms such as the integration of science, math, and engineering.

Future Research

Teachers: Supports that encourage innovation. Future research involving teachers in curriculum design projects should begin to explore how a variety of supports intended to trigger innovation, rather than conformity and compliance with traditional norms, are embraced. It may be necessary to search for non-traditional resources and activities largely because the research base advocating for teachers to be designers is just beginning to emerge. It may also be of benefit to work with non-traditional designers or involve professional instructional designers in the design process if for anything to indicate to the teachers involved in the project that they are being asked to step into a new world, possibly that differs from how they currently view their professional role. The "design thinking" movement that has been developing in the recent decades may also be worth considering when asking teachers to design curriculum resources that stand out or are non-traditional from those typically seen in science and math classrooms. Opening up and further developing the research base that involves working with designers who also teach contains opportunities before, during, and after the design process that are in need of exploration if the trend of involving teachers in curriculum design projects pervades.

Coaches: Interactions and conversations that promote innovation via encouragement. Encouraging someone to be innovative is all that can really be done. You cannot tell someone or require that someone be innovative, all you can do is provide a space and the capacity for innovation to occur. Creating this space, and exploring the interactions that can occur in this space provides the opportunity for future research to ensue. Coaches, being the main contact point for any team of teachers during the design process, can play a significant role in fostering the type of design space and conversation needed to occur to promote more design-centric PD. Perhaps new PD models for science teachers are in order, given the complexity of the work now being proposed during the PD. Professional development coordinators and facilitators are no longer just interested in developing a teacher's content knowledge understanding or addressing one's pedagogical approach, they are asking teachers to be designers and writers. Providing teachers with slogans of assessment, frameworks to work within, content standards to address, and a coach to assist them during the process may not be completely appropriate. Instead, it may be worth exploring how the influence and impact of a variety of coaching roles has on during the design process. Perhaps teachers need motivators, critical evaluators, assessment experts, content experts, or philosophers to work with during the design process. The possibilities remain unexplored and potentially fruitful. What is more certain is that maintaining and perpetrating typical PD supports for teachers during the design process will only result in learning experiences and curriculum that conform to those more commonly seen in science classrooms throughout the past few decades.

Curriculum: Varying starting points for design. Insightful ideas for a potential activity or curricular unit are highly sought after. Once a particular curriculum resource is discovered as being innovative, valuable, and capable of providing unique learning experiences it spreads throughout classrooms across the country and perhaps the world via social media. However, discovering a truly unique and novel idea to develop into an engineering design challenge or unit is not easily accomplished. This takes time, effort, resources, knowledge, and the ability to find connections amongst the previously unconnected. The challenge of getting that initial idea, finding that series of related concepts, or discovering that engaging context for a unit to be branched under may not be feasible for everyone in a set amount of time from scratch. Perhaps the task can be scaffolded or differentiated with varying starting points for design teams to begin the process given the team's preferences, make up, and overall need. There is no crime in starting off, or jump-starting the process for a team of designers who are also teachers. Perhaps a series of connected content standards can be presented as containing a unique relationship that when integrated support student learning in each unique discipline simultaneously; or perhaps an engaging context or two can be presented as being potentially useful for the integration of differing content standards. Lastly, a potential set of materials and associated processes that could be accomplished with a given set of materials could be presented for use during a unit's engineering design challenge, arguably the most difficult aspect of a STEM-integrated curriculum. Given that materials have been found to be a limiting factor when teachers are involved in design (Taylor, 1980) this is justifiable. Again, there is no harm in supporting teachers in this manner if the goal is to develop the best curriculum possible, and not necessarily get teachers to be outstanding designers. There is also no harm in providing a variety of starting points for a large group of teachers to run with, because the nuts and bolts of each specific unit will take on differing paths once they diverge from that original starting point.

This is where the opportunity for research lies. What types of starting points have the most impact on a team of teachers during the design process? What types of challenges or opportunities are afforded when a variety of differing starting off points are provided (e.g. content connections or overall contexts)? Again, it can be justly said that simply asking teachers and coaches to essentially start from scratch with a variety of content standards to address, and a vague model of assessment for any designed curriculum to strive towards, is not an ideal starting point. This is especially true given the amount of time needed to discover these vital aspects of a STEM-integrated curriculum and the amount of time teachers typically have to partake in the curriculum design process. Giving them a head start, that has been truly contemplated and initially developed, would be a welcome addition to most teams of teachers at the beginning of the design process and would not have to be required for those who feel they are up to the task without training wheels; which some inevitably will be. In varying the starting points for curriculum design, by providing foundations, ideas, or contexts to more fully develop a variety of research opportunities are created, each of which would require a variety of methods and research questions to explore.

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Appendices (A-B-C)

A. INSTRUMENTS

- Individual Semi-structured Interview Protocol – (TEACHER)

Protocol Guidelines:
The interview protocol is designed to be responsive and emergent. The following prompts and questions may be modified during the course of the interview(s).

General Protocol Sequence:
Greeting: Interviews will all start with casual "small talk" meant to elicit a general demeanor of the participant prior to proceeding into the protocol questions/prompts.
Recording: Participants will be made aware that all interviews will be audio recorded for later analysis.
Questions/Prompts: Upon initially responding to questions and prompts, participants will be asked to expand upon their responses for further depth and clarity. For example, "What does that look like?" or, "Please tell me more about that." Participants will also be offered the opportunity to come back to a question at a later time if needed.
Closure: As the interview comes to a close, the participant will be asked, "Is there anything else you would like to add or expand up?". Following this question and response, the recorder will be turned of so next steps the study can be discussed with the participant.

Curriculum Design Influences - Open-Ended Interview Question Pool:
Introduction: The purpose of this interview is to better understand your experiences during EngrTEAMS. I'm interested in hearing your story and learning about what the curriculum design process means to you. Your individual interpretations, voice, and feelings have merit as we better learn how to work with teachers during the curriculum design process. With that said, please feel free to take as long as needed when responding to a question. If you feel I'm not asking the right questions during the interview, please feel free to interject, change the question, and respond accordingly. If I ask a question that is unclear or that you would like to have more time to think about, please say so and I will repeat the question or return to it at a later time.

1. How did you get involved with EngrTEAMS?
    a. Who, if anyone, influenced your participation in EngrTEAMS?
    b. Tell me how this occurred.
2. What have you enjoyed about EngrTEAMS?
3. What, if anything has been frustrating about EngrTEAMS?

Curriculum Design - Open-Ended Interview Question Pool:

4. What have you been thinking about as your team has been creating a STEM-integrated unit for your classroom?

   a. Possible prompts: STEM Integration Curriculum Assessment, Standards, Engineering Design Challenge, Model-Eliciting Activity MEA, Data Measurement/Analysis.
5. What are 3 or so major events that stand out in your mind as being important to the curriculum design process?
   a. Could you describe each one?
   b. Why do you think this is important?
   c. How do you think this event affected the curriculum your team designed?
6. What have you been working on with your team?
7. In regards to curriculum design, what are you good at?
8. What has challenged you during the curriculum design process?
   a. What have you felt like you've had to "bite your tongue" on while working with your team?
9. How have you used science standards during the curriculum design process?
   a. How have you used math standards during the curriculum design process?
   b. How have you used engineering standards during the curriculum design process?
10. Who has been the most helpful to you during the curriculum design process?
    a. How has he/she been helpful?
11. How do you think the unit your team is designing will meet your students' needs?

Reflective - Open-Ended Interview Question Pool

12. What are 3 or 4 strategies that you have picked up during EngrTEAMS that have helped you better understand curriculum design?
    a. After participating in the process of creating a STEM integrated unit, what advice would you have to a (veteran or rookie) teacher just beginning the process?
13. What do you think the other members of your group value about your participation in the curriculum design process?
    a. Why?
14. If you were to take on the role of a coach in your team, how, if at all, do you think your role would be different?
15. What are some similarities and differences between EngrTEAMS and other, similar professional development opportunities you've participated in?

--- Close ---

16. What do you think I should know about to better understand your experiences during EngrTEAMS?

- Individual Semi-structured Interview Protocol – (COACH)

Protocol Guidelines:
The interview protocol is designed to be responsive and emergent. The following prompts and questions may be modified during the course of the interview(s).

General Protocol Sequence:
Greeting: Interviews will all start with casual "small talk" meant to elicit a general demeanor of the participant prior to proceeding into the protocol questions/prompts.
Recording: Participants will be made aware that all interviews will be audio recorded for later analysis.
Questions/Prompts: Upon initially responding to questions and prompts, participants will be asked to expand upon their responses for further depth and clarity. For example, "What does that look like?" or, "Please tell me more about that." Participants will also be offered the opportunity to come back to a question at a later time if needed.
Closure: As the interview comes to a close, the participant will be asked, "Is there anything else you would like to add or expand up?". Following this question and response, the recorder will be turned of so next steps the study can be discussed with the participant.

Curriculum Design Influences - Open-Ended Interview Question Pool:
Introduction: The purpose of this interview is to better understand your experiences during EngrTEAMS. I'm interested in hearing your story and learning about what the curriculum design process means to you. Your individual interpretations, voice, and feelings have merit as we better learn how to work with teachers during the curriculum design process. With that said, please feel free to take as long as needed when responding to a question. If you feel I'm not asking the right questions during the interview, please feel free to interject, change the question, and respond accordingly. If I ask a question that is unclear or that you would like to have more time to think about, please say so and I will repeat the question or return to it at a later time.

Opener -

1. What has your role as a coach been during EngrTEAMS as your team has been designing your unit?

Curriculum Design - Open-Ended Interview Question Pool:

2. What has influenced your thinking about the unit you and your team are co-developing?
    a. Who, if anyone, has influenced your thinking about the unit?
3. What are 3 or so major events that stand out in your mind as being important to the curriculum design process?
    a. Could you describe each one?
    b. Why do you think this is important?
    c. How do you think this event affected the curriculum your team designed?
4. What roles have the members of your team taken on?
    a. What tasks do certain members of the team take on?

    b. How is task determination decided?
5. How have you gauged the contributions of the members of the team?
    c. What have you done to support your team during the curriculum design process?
6. What would you say you are good at in regards to curriculum design?
7. What has challenged you as a coach during the curriculum design process?
8. How have you used science standards during the curriculum design process?
    a. How have you used math standards during the curriculum design process?
    b. How have you used engineering standards during the curriculum design process?
9. Who has been the most helpful to you during the curriculum design process?
    d. How has he/she been helpful?

Reflective - Open-Ended Interview Question Pool

10. What are 3 or 4 strategies that you have picked up during EngrTEAMS that have helped you better understand curriculum design as a coach?
    a. After participating in the process of creating a STEM integrated unit, what advice would you have to a first time coach just beginning the process?
11. What do you think the other members of your group value about your contributions as a coach during the curriculum design process?
    b. Why?
12. If you were to take on the role of a teacher in your team, how, if at all, do you think your role would be different?

--- Close ---

What do you think I should know about to better understand your experiences during the curriculum design process?

- Participant Reflection Prompts -

-- Name (optional) -- ___________________________

-- Group/Content Area -- (Earth Science, Physical Science, Life Science)

-- Role -- (Teacher, Coach)

-- Date -- ___________________________

-- Directions -- Please use this form to reflect on the day's events, activities, and revelations during EngrTEAMS.

You may choose to provide responses to the following questions in one of two ways:

(1) Clearly handwrite your responses directly on this sheet of paper or a supplemental sheet of paper that is attached to this sheet.

(2) Responses can also be provided digitally via a typed response by filling out the secure Google Form.

Questions:

1) What were the key messages and/or takeaways from today's workshop sessions <u>and</u> how can you connect these to the curriculum you and your team are co-designing?
2) What difficulties, barriers, or challenges did you or your team encounter today?
3) Recap the day in your mind. What activities did you engage in with your team?
4) Recap the day in your mind. What responsibilities did you take on in your team today?
5) In response to today's activities, what do you plan to do next?
6) What, if anything, do you need from EngrTEAMS staff as a result of the day's activities?

B. INFORMED CONSENT

PRINCIPAL INVESTGATOR: JUSTIN MCFADDEN

TITLE OF PROJECT: "Teachers as Designers: The Iterative Process of Curriculum Design Focused on STEM Integration"

INFORMED CONSENT DOCUMENT

This Informed Consent will explain the nature of being a participant in this research study. It is important that you read this material carefully and then decide if you wish to participate.

Purpose:

The proposed study is intended to explore the curriculum design process of teams of science teachers and graduate students vested in integrating science, technology, engineering, and mathematics [STEM] into their science classroom. The study aims to provide insight into the following phenomenon: (1) The curriculum design process of curriculum design teams involved in STEM integration (2) The negotiated roles design teams take on with their colleagues during the curriculum design process. (3) The influential drivers behind the curriculum design decisions of design teams involved in curriculum design focused on STEM integration.

Procedures:

If you agree to be a participant in this study you will be permitting the researcher to the following:

a. Permit the researcher access to the conversations you have with your design team during the EngrTEAMS professional development workshop that will be recorded by a digital audio recorder that may be attached to a lapel microphone worn by a colleague or yourself (if permitted).
b. Permit the researcher access to digital and non-digital artifacts that are created amongst your team during the EngrTEAMS professional development workshop. Digital artifacts include but are not limited to those created on a university-sponsored Google Drive account. Non-digital artifacts may include whiteboard drawings, scratch sheets of paper, or prototype designs that are created while working in your design team.
c. Permit the research access to written and/or electronic reflections about your experiences during the professional development workshop.
d. Participate in no more than 2 audio-recorded individual interviews lasting roughly 1 hour.

Possible Risks/Discomforts:

There are two potential risks/discomforts involved in this study. The first is a time commitment outside of the standard professional development day for an individual interview or interviews. The second is the potential for feelings of awkwardness of discomfort experienced while being audio recorded during any professional development sessions or individual interviews. You may at any time request to modify your participation in this study or outright remove yourself from the study.

Benefits of Participation:
There are no guaranteed benefits to participants in the study. Contributing to the body of knowledge aimed at better understanding the curriculum design process of design teams is an anticipated benefit. You may find the added opportunities for reflection about your experience in the professional development to also be beneficial.

Alternative Procedures:
There are no alternative procedures; except not to participate.

Confidentiality:
All attempts will be made to see that any information yielded in this study are kept confidential. All audio recordings and other data will be maintained on the researcher's password protected computer for up to five years. Identifiers will be removed. The recordings and all other data will be archived on a password protected independent data device for up to ten years.

The results of this study may be published and/or presented at conferences. In any sort of article that is published, identifiable information will not be included. However, you or someone whom knows you closely might be able to recognize your information.

Contact:
If you have any questions you may contact: Justin McFadden at (320) 321-9610 or mcfad062@umn.edu. You may also contact my advisor: Gillian Roehrig at (612) 625-0561 or roehr013@umn.edu. If you have any questions or concerns regarding this study and would like to talk to someone other than the researcher(s), **you are encouraged** to contact the Research Subjects' Advocate Line, D528 Mayo, 420 Delaware St. Southeast, Minneapolis, Minnesota 55455; (612) 625-1650.

Participation in this research experiment is voluntary: You may refuse to participate. You can quit at any time. If you quit or refuse to participate, the benefits or treatment to which you are otherwise entitled will not be affected.

Statement of Consent:
By signing below, you confirm that you have read or had this document read to you. You will be given a signed copy of this informed consent document. You have been given the chance to ask questions and to discuss your participation with the investigator. You freely and voluntarily choose to be in this research project.

Signature of Participant: ________________________ Date: _____________________
Printed Name of Participant: _____________________

Signature of Investigator: ________________________ Date: ____________________

C. TRANSCRIPTION CONVENTIONS[1]

Definition	*Code*
Descriptive text	( )
Laughter	@,@
Overlapping speech	[ ]
Increased volume	UPPERCASE
Indicates emphasis	underline
Decreased volume	° °
Animated tone	!
Latched or continuous speech	=
Inaudible speech or	( )
Stretching of sound	:
Short pause	(.)
Longer pause	(..)
Dropped or interrupted utterance	/
Falling intonation	↓
Rising intonation	↑
Faster relative speech	< >

[1] Transcription conventions are adapted from the Jefferson system. The format of the conventions table is modeled on one used in Majors (2007).